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ARTIFICIAL SATELLITE APPROXIMATIONS

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The material presented here is intended to assist the lone observer in following an artificial satellite which is bright enough to be seen by the unaided eye or at its faintest, with 7 × 50 binoculars. It is assumed that the satellite crosses the equator at an angle of at least 55°, hence travels at least to latitude 55°, north and south. It is further assumed that the latitude of the observer is at least ten degrees less than that of the northernmost (or southernmost) point of the satellite's travels.

One may reasonably assume that the satellite travels in a counterclockwise direction around the earth as viewed from a point above the north pole of the earth. In launching a satellite in this direction, one takes advantage of the energy contributed by the rotation of the earth. This may amount to as much as 1,000 miles per hour if the launching takes place at the equator.

First we shall attempt to determine the period in which the satellite revolves around the earth, measured from the time it crosses a particular latitude until it next crosses the same latitude going in the same direction. This period depends on the average distance of the satellite from the centre of the earth, or the radius of the orbit if it is circular. For a theoretical satellite just skimming above the surface of the earth and undisturbed by air friction, the period would be 84.5 minutes. A hundred miles above the earth, the period would be 87.7 minutes; this may be taken as a reasonable lower limit to the period of an artificial satellite since atmospheric friction will quickly destroy a satellite at this elevation. Table I gives for periods of an integral number of minutes, 85 to 114, the average height of a satellite above the earth.

TABLE I

SATELLITE'S ORBITAL PERIOD VS. AVERAGE HEIGHT ABOVE EARTH

P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H
85	15	95	322	105	617	115	903	125	1181	135	1452	145	1716	155	1974
86	47	96	352	106	646	116	931	126	1209	136	1479	146	1742	156	2000
87	78	97	382	107	675	117	959	127	1237	137	1505	147	1768	157	2025
88	109	98	411	108	704	118	987	128	1263	138	1532	148	1794	158	2050
89	140	99	441	109	733	119	1015	129	1290	139	1558	149	1820	159	2076
90	170	100	471	110	761	120	1043	130	1317	140	1585	150	1846	160	2101
91	201	101	500	111	790	121	1071	131	1344	141	1611	151	1872	161	2126
92	231	102	529	112	819	122	1099	132	1371	142	1637	152	1897	162	2151
93	261	103	559	113	847	123	1126	133	1398	143	1664	153	1923	163	2177
94	292	104	588	114	875	124	1154	134	1425	144	1690	154	1948	164	2202
95	322	105	617	115	903	125	1181	135	1452	145	1716	155	1974	165	2227

P: sidereal period of satellite in minutes.
H: average height of satellite above earth in miles i.e. average distance of satellite from centre of earth in miles minus 3960 miles.

Suppose that one observes a satellite passing over one evening at 6:12 p.m. and again the next evening at the same observing position at 6:00 p.m. In 1,428 minutes (one day less twelve minutes), it has made a *whole number* of revolutions, either 16, or some smaller integral number of trips. If this number is 16, the period is clearly 89.25 minutes; if 14, the period is 102 minutes and corresponding to each of these, there will be a specific average height above the earth. If one knows an approximate value of this period, one can quickly determine the number of trips completed in the interval and obtain a more precise estimate of the period. Likewise from newspaper announcements of the times when a Sputnik is expected, one can get a close approximation to the period which was used in determining the announced times.

Next we may consider how one may determine whether the path of the satellite will appear to be drifting east or west from day to day with respect to a given observer. If there are exactly an integral number of revolutions in 24 hours, the path will seem to drift westward in longitude about 4.1° per day. 1° of this will be due to the revolution of the earth about the sun and 3.1° will be due to the regression of the nodes. [The latter quantity depends on the angle the orbit makes with the equator, among other things; hence it may change from satellite to satellite.]

If the satellite makes a whole number of revolutions in $(1440 + M)$ minutes, where $M < P/2$, the daily westward drift of the path in longitude will be $(4.1 + M/4)°$.

If the satellite makes a whole number of revolutions in $(1440 - M)$ minutes, the apparent daily drift will be eastward $(M/4 - 4.1)°$ if $M > 16.5$, or westward $(4.1 - M/4)°$ if $M < 16.5$.

If P is the period of an artificial satellite in minutes, $[P(1 + 1/90)/4]$ gives the approximate difference in longitude in degrees between two consecutive passages of the same sort (ascending or descending, where going north is counted as ascending) across a given latitude circle.

In general, an artificial satellite will not be seen unless (1) the observer has a clear dark sky, (2) the satellite is high enough above the earth to be illuminated by sunlight and (3) near enough to be above the observer's horizon. Table II can be used in two ways, (1) to find how high a satellite must be above the earth to be in sunlight at a given distance from the sunrise-sunset line and (2) how high a satellite must be above the earth to be seen at a given distance. No allowance has been made for atmospheric refraction in this table. Sometimes when a satellite is high enough, it can be seen on two consecutive passages from a single position. This was true of Sputnik I on several occasions. Sputnik II which at its highest has been considerably higher than Sputnik I, has been seen at a distance of 2,500 miles by an observer on the ground.

TABLE II

SUNSET–SUNRISE AT ELEVATIONS

d	D	d	D	d	D	d	D	d	d	d	D	d	D	d	D
0	0	130	869	260	1213	390	1467	520	1673	650	1848	780	2000	910	2136
10	244	140	901	270	1235	400	1484	530	1687	660	1860	790	2011	920	2146
20	345	150	932	280	1256	410	1501	540	1701	670	1872	800	2022	930	2155
30	422	160	961	290	1277	420	1518	550	1716	680	1885	810	2033	940	2165
40	487	170	990	300	1298	430	1534	560	1729	690	1897	820	2044	950	2175
50	543	180	1017	310	1318	440	1551	570	1743	700	1909	830	2054	960	2184
60	595	190	1044	320	1338	450	1567	580	1757	710	1921	840	2065	970	2194
70	642	200	1070	330	1357	460	1582	590	1770	720	1932	850	2075	980	2203
80	685	210	1096	340	1376	470	1598	600	1783	730	1944	860	2085	990	2212
90	726	220	1120	350	1395	480	1613	610	1797	740	1955	870	2096	1000	2221
100	765	230	1144	360	1413	490	1628	620	1810	750	1967	880	2106		
110	801	240	1168	370	1431	500	1643	630	1822	760	1978	890	2116		
120	836	250	1191	380	1449	510	1658	640	1835	770	1989	900	2126		
130	869	260	1213	390	1467	520	1673	650	1848	780	2000	910	2136		

$\cos D = 3960/(3960 + d)$ d in statute miles, D in nautical miles.

There are certain advantages in using the time when a satellite reaches the northernmost point in each revolution. These successive passages can be numbered V_1, V_2, etc. By adding or subtracting the appropriate small amount of time to an observed time of passage at a given observing site, one can find and record the time at the nearest vertex. This term *vertex* has been borrowed from the navigator who uses the term to describe the point of a great circle nearest the north (or south) pole. By this device, one can use observations made at a number of different places to keep

informed of the way in which the period of a satellite is decreasing and hence how the body is falling toward the earth.

To determine the time of a vertex passage, one may use the navigation table (A. A. Ageton) with the following formulae:

$$B(L_v) - B(L) = A(C)$$
$$B(C) - A(L_v) = A(t_v)$$
$$B(L) + A(t_v) = A(d_v)$$

where L_v is the latitude of the vertex of the path, L is the latitude of the observer, C is the angle between the path and the observer's meridian, t_v is the difference between the longitudes of the observer and of the vertex of the path which goes through the observer's zenith, d_v is the angular distance (measured at the centre of the earth) from the observer to the vertex.

The correction to be applied to the observed time of a passage to obtain the corresponding time of a vertex passage is $(d_v/360^\circ)P$ minutes. This correction is minus for an observation made on a descending branch, plus for an ascending branch.

The above formulae hold for a satellite path around an earth which is assumed not rotating. The correction to obtain vertex time is satisfactory as given, but small corrections must be made to C and t_v to allow for the earth's rotation.

The reader is encouraged to keep his own record of vertex passages in order to appreciate the differences in the counts kept by various authoritative agencies.

One of the most interesting problems arising in connection with an artificial satellite is that of determining where the satellite will enter or leave the shadow of the earth. If one knows the approximate time and height of the passage in question, one can mark on a globe the great circle which will represent the sunrise-sunset line at the given time. Using Table II, one can enter with d, the elevation in statute miles and obtain the distance D, in nautical miles. The desired point of entrance to or emergence from the earth's shadow will be the point on the path of the satellite, sketched on the globe, which is D nautical miles from the sunrise-sunset line and on the opposite side of it from the sun.

References

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CLASSIFICATION OF SOLAR PROMINENCES*

By F. Shirley Jones

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Accurate knowledge of the activity above the solar chromosphere has been acquired only slowly. The early astronomer interested in the sun's outer atmosphere could observe the eclipse phenomena and the solar prominences for less than 150 minutes during his whole lifetime, even if he could have observed every eclipse, from wherever it was visible on the earth, and had clear skies.

Ninety years ago, however, a way was discovered to observe the prominences in full sunlight. While watching the eclipse of August 18, 1868, through a spectroscope, J. Jansen of the Meudon Observatory in France concluded that the light of the prominences came from a very few bright lines in the spectrum. These were so brilliant that he felt they should be visible without an eclipse. The next morning he confirmed this. After more than a month of observing parts of prominences with a spectroscope, he sent word of his discovery to the Paris Academy of Sciences. His was the second letter announcing the same discovery to arrive at the Academy that day. The first was from the English physicist, Sir Norman Lockyer. As early as 1866 Lockyer had ordered a spectroscope of wide dispersion for the express purpose of viewing, without an eclipse, the bright lines he expected the prominences to show. His instrument arrived in October 1868, and he independently made the discovery reported by Jansen. A year later Sir William Huggins saw whole prominences at the edge of the uneclipsed sun when he used a very wide slit in his spectroscope.

Regular studies of solar prominences with the wide slit technique then began. The Italian astronomers Secchi and Respighi were foremost in this field. With only visual techniques, painstakingly they made drawings of hundreds of prominences and were impressed with the variety of their shapes and activity. Secchi made the first attempt to find some orderly pattern in the multitude of shapes and motions he observed. He realized that only when a satisfactory scheme of classification had been worked out could the theoretician explain the exciting activity. Secchi decided that the prominences fell in two main categories, the long-lived and the short, which he called *quiescent* and *eruptive*.

*An address presented to the Wellesley Chapter of Sigma Xi on October 30, 1957.

The next advance in solar studies came in 1891 with George Ellery Hale's invention of the spectroheliograph. In this instrument, a slit and a photographic plate replace the eye in the spectroscope. The second slit selects the desired spectrum line. The photographic plate is moved as the solar image is moved across the first slit, so that a picture of the solar disk is built up slit-width by slit-width. Such monochromatic pictures also show the prominences. Most spectroheliograms are in the light of the Fraunhofer H or K lines of calcium or in the H-Alpha line of hydrogen.

Later, a refinement to Hale's spectroheliograph was added by the McMath-Hulbert group, who adapted time-lapse photographic techniques to obtain motion picture studies of the prominences. Their spectrohelio-kinematograph uses oscillating slits instead of images. When prominences alone are to be studied a disk is placed in the focal plane to obscure the bright face of the sun.

The Mount Wilson astronomer, Edwin Pettit (1920, 1943) studied prominences in spectroheliograms for many years, and he suggested a scheme of classification that is more detailed than Secchi's and has six main classes. *Active* prominences appear as filaments on the disk but show activity connected with an adjacent sun-spot area. A prominence is *eruptive* when it rises as a whole to a height above the chromosphere, and either disappears there or rains back to the sun's surface in streamers. Pettit found the eruptive prominences so spectacular he made a special study of them. A *spot* type prominence may be either a spurting jet or a series of loops, and appears only in active spot regions on the sun. *Tornadoes* are the tall narrow prominences with a helical filamentary structure. His fifth class, the filamentary prominences and mounds that remain substantially unchanged for hours or days, he called *quiescent*. *Coronal* streamers are short-lived elongated filaments that curve down from the corona.

The next advance in prominence research came in 1930. Until then, the corona could not be seen every day even when the telescopes with their occulting disks were installed on mountain tops. Bernard Lyot of Meudon suggested, as a reason, that the optical parts were imperfect. A lens that had the tiniest bubble or seed in the glass, or whose surface had even a minute sleek on it, was not good enough. Such imperfections, combined with internal reflections in the instrument, scattered enough light to drown out the weak radiance of the corona. Lyot took great pains to turn out a perfect objective. To test it, he and his assistants, with the instrument on their backs, skied to the top of the Pic du Midi in the

French Alps. The tests proved Lyot right, for the corona and prominences were clearly visible. He named his instrument a "coronagraph".

In 1933 Lyot made another significant contribution. He proposed a monochromatic filter which permitted the study of prominences without a spectrograph. This filter uses the bi-refringence of quartz and the selective transmission of polaroid to transmit a narrow range of wavelengths. A good filter will pass at H-alpha a band only four angstroms wide. The best filters transmit less than an angstrom. The combination of a coronagraph and a bi-refringent filter results in an instrument that is uniquely suitable for studying prominences.

Inspired by Lyot's results, Donald H. Menzel instigated the construction of a similar coronagraph and filter for the Harvard College Observatory. It was put into operation at Climax, Colorado, by Walter O. Roberts in 1940, and has been patrolling the edge of the sun ever since.

In 1950 another such solar observatory was erected on Sacramento Peak in New Mexico due to the efforts of Menzel and his associates at Harvard. At present John W. Evans superintends its operation for the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command. At Sacramento Peak a whole battery of instruments keeps track of the activity on the sun: a 2.5-inch flare-patrol camera, a sun-spot telescope, a 4-inch coronagraph and spectrograph for studies of the coronal spectrum, a 6-inch coronagraph and Lyot filter for taking motion pictures of prominences and the inner corona, a 15-inch telescope for large-scale pictures of the chromosphere and prominences, and a 16-inch coronagraph, the largest in the world at the present time. Accessory instruments used with the 16-inch are a Littrow spectrograph with a focal length of 13 metres and a Lyot filter of 0.65 angstrom bandpass. A similar 16-inch coronagraph is planned for the High Altitude Observatory at Climax.

The Menzel-Evans Scheme of Classification. Menzel and Evans (1953) studied intensively the prominences recorded in the films obtained with these coronagraphs, and concluded that electromagnetic forces determine the behaviour of prominences. Differences in form, motion, and supporting mechanism are "traceable to the differences in the magnetic field at their place of origin and in the space where they were observed. On this basis it is not difficult to see why prominences over sun-spots should be very different from those not directly associated with spots."

With this in mind, Menzel and Evans (1953) suggested a sheme of

classification somewhat different from Pettit's, based on: (a) the motion of the material within the prominences, upward or downward; (b) association of the prominence with sun-spots; (c) its characteristic form. Using suggestive letters they developed a code, in which *A* denotes a prominence in which the luminous matter flows downward to the chromosphere from above. *B* denotes motion of luminous matter from below toward the corona. Prominences connected with spot activity are labelled *S*, the others *N* for non-spot. To any pair of the four possible combinations of these four letters is added a small letter that stands for a distinct prominence form, which can be visualized by the name given the class.

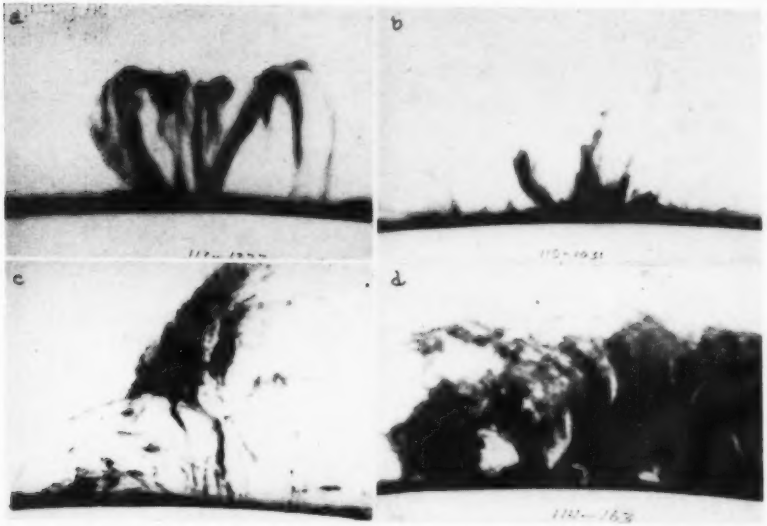
The resulting scheme is as follows:

A. Prominences originating from above in coronal space
- *S*. Spot prominences:
  - *l*. Loops
  - *f*. Funnels.
- *N*. Non-spot prominences:
  - *a*. Coronal rain
  - *b*. Tree trunks
  - *c*. Trees
  - *d*. Hedgerows
  - *e*. Suspended clouds
  - *m*. Mounds.

B. Prominences originating from below in the chromosphere
- *S*. Spot prominences:
  - *s*. Surges
  - *p*. Puffs.
- *N*. Non-spot prominences:
  - *s*. Spicules.

Active sun-spot regions are easily recognized at the sun's limb by the presence of *ASl*, *ASf*, *BSs*, or *BSp* type prominences. The *ASl*'s are loops or partial loops (See figure *a*). The prominence material appears as bright knots high above the chromosphere which flow downward on both sides of gracefully curved arcs. At times the loops appear as a series of parallel curves; at other times they seem to radiate from a common origin, an appearance similar to that of a "slinky" toy when several turns are pinched together at the bottom.

A *funnel* type prominence, *ASf*, is shaped like an inverted cone, and generally has a sharp boundary at one or more places on its sides (See figure *c*). Continuous streams of material emerge from the bottom, sides,



Types of solar prominences: (a) Loop prominences in a sun-spot region–Type *ASl*; (b) Surges in a sun-spot region–Type *BSs*; (*c*) Funnel type prominences close to a sun-spot region–Type *ASf*; (d) Hedgerow prominences–Type *ANd*.

or top, or all three, to fall along curved paths to the sun's surface. Menzel believes the flow in the funnel to be parallel to the magnetic lines of force whose position is in turn determined by the moving matter.

Two types of prominences show ejection of material from the lower layers of the chromosphere. The *BSs*'s are *surges* that rise from the spot region (See figure *b*). The activity is repeated over and over with variations. At times a surge emits a fast-moving mass resembling a bullet; at other times the *BSs* appears as a huge bright mound that eventually bulges upward to spew forth luminous matter. Surges frequently occur in regions where loops are or have been present. If the ejected material is in the form of a small detached cloud, the prominence is labelled a *puff* or *BSp*.

Brief brilliant *flares* also occur in sun-spot regions. It is difficult to decide just what prominence form a flare has. Menzel believes that initial phases of loop prominences may appear as flares; to the writer, more often, they appear as blunt tangential surges. Flares are so brilliant that when they are photographed with the proper exposure for ordinary prominences, the picture shows only a burst of over-exposed blobs.

Most non-spot prominences fall into a family of closely related groups. In addition there are two types that differ distinctly from this family. *ANa*'s are *coronal streamers* that rain down from high in the corona as single curved streamers or a sheet of streamers. Columnar prominences that resemble *tree trunks* are classified *ANb*. Sometimes these grow branches as the prominence material streams sidewards from the standing column. Fan-shaped prominences resembling shrubs or *trees* are classed ANc. These are so similar to low funnels that the two types are probably closely related. Lack of any other evidence of sun-spot activity in many cases suggests that the *ANc*'s are a distinctive class. Occasionally, however, an *ANc* near a spot rises and displays activity typical of a funnel. Some trees and tree trunks disintegrate by abruptly ascending, to move laterally along the sun's limb and then rain back in a ribbon of twisting filaments.

A group of two or more trees or shrubs is called a *hedgerow* and labelled *ANd* (See figure *d*). Most of the prominence material appears in this form. In H-alpha spectroheliograms of the sun's disk they appear as dark filaments. Occasionally two trees in a hedgerow form an arch which may or may not ascend into the corona. The *ANb*'s, *ANc*'s, and the *ANd*'s form a family of closely related types. All three are occasionally observed to disappear as a distinct form, only to reappear farther along the sun's edge. In the neighbourhood of spots the trees and hedgerows sometimes exhibit a tendency to send out streamers, which at times appear to be moving both from left to right and from right to left, as though they were part of a gigantic whirlpool seen edge-on. Some non-spot prominences are so close to spot activity that they exhibit some form of interaction with the spot phenomena; these are identified in the work about to be described (see Menzel and Jones, 1956, 1957) by an asterisk added to the original class, e.g., *ANd**.

A *mound* or *ANm* is a solid mass of downward-moving material. At times such mounds have a thin streamer emerging from the top. Mounds remain substantially unchanged for long periods.

An isolated *cloud* of prominence material is designated an *ANe*. Some clouds look like detached hedgerows; others show no filamentary structure.

The only prominences that have upward-moving material and are present at all latitudes on the sun are the *spicules*. These *BNs*'s form a grass-like carpet of small jets over large arcs of the sun's limb. Their detection demands the best of seeing.

The Menzel-Jones Classification Project. At Dr. Menzel's suggestion I started in January 1956, to classify, according to this scheme, all promi-

nences recorded throughout a sun-spot cycle. Such a statistical survey should be based on a series of observations as complete and homogeneous as possible. The only continuous and fairly complete record available is to be found in the daily survey films taken with the Climax coronagraph since 1942, and with the Sacramento Peak coronagraph since 1950. These films form the basis of the present study.

Each survey picture shows 70° of sun's edge. A series of eight pictures at position angles 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° record completely the whole circumference with sufficient overlap to show most prominences twice. There are several exposures of various duration times at each position angle. The long exposures are measured for size, and the fainter pictures showing less contrast are generally used for the classification.

Since Menzel and Evans had based their classification scheme on motion picture studies, it is necessarily a dynamic one. But motion pictures are not made of the whole solar edge, but only of the more spectacular events. The present study, however, aims to measure and classify all the prominences found on the surveys and on the motion picture films, to discover just how consistently classes can be assigned to those prominences seen in the still pictures only. Comparison of the results obtained so far for those prominences that are common to both the still and the moving pictures indicates a reasonable amount of success.

The survey pictures are made on 35-mm. film and are assembled in rolls 100 feet long, each roll containing the record for fifteen or more days. The rolls are projected with a 500-watt projector, equipped with a fan and a double frame strip film adapter, on a bristol board screen. Near the bottom of the screen is drawn a circular arc 80° wide, divided radially into degrees. Above this arc are concentric arcs which, with radial lines, form a polar co-ordinate grid for estimating areas.

In measuring the surveys, one first notes the position angle of the beginning and end of each prominence, to obtain a measure of the length of the prominence along the solar limb. The smaller prominences, such as spicules, are less than 0°.5 in width. The longest prominences are tremendous, spreading almost the full width of the picture. On June 4, 1946, for example, a huge arch occurred that measured more than 70° from one end to the other.

The position angle of the centre of intensity of each prominence is noted next; this is a somewhat personal estimate of the point around which brightness and area balance. A symmetrical prominence of uniform brightness would have its centre of intensity midway between the ends, but most prominences lack this symmetry and uniformity in bright-

ness. The position angle of the centre of intensity is converted into heliographic latitude to permit study of the distribution of the prominence classes on the ball of the sun.

Since the original films were not standardized, it is not possible to attempt precise photometry, but the observers did attempt to control procedures in both photography and development. From the exposures that show the most detail, the total intensity of each prominence is estimated. This is called the "importance" of the prominence, and is denoted by a letter. D— is assigned to the most insignificant prominences. Then D, D+, C−, C, C+, B−, B, B+, A−, A, A+, indicate increasing total intensity, with A+ for the most impressive prominences.

To measure the area of a prominence, I count "squares" on the polar co-ordinate grid. Each "square" is equal to 50 prominence units; and each prominence unit is a "rectangle" one heliocentric degree wide and one geocentric second high. At the sun's limb one prominence unit is 8.8×10^6 sq. km. Needless to say, at great heights it would be greater. However, prominences are generally close to the limb. Small areas are easily estimated to the nearest 5 p.u. Large prominences are difficult to measure, and estimates of their areas are considerably less accurate. For prominences of more than 500 p.u., areas are estimated to the nearest 50 p.u.

Finally I assign each prominence to one of the classes listed above, unless a definite decision is impossible. An additional comment is made when some unusual feature is noted.

When all the prominences recorded in a given year have been assigned to categories, the classification of prominences from the survey films are compared with those from the motion picture films.

This study for the years 1949 to 1952 inclusive has now been completed; 78 per cent. of the prominences were assigned to identical classes in both media, 16 per cent. were assigned to closely related classes, and 6 per cent. to classes that are widely different.

When the measures of position angle and area and the classification for all prominences in a given year are completed, they are published in catalogue form (Menzel and Jones, 1956, 1957). To analyze trends in amount, position, and type of prominence activity, the year is divided into thirds (Larmor, 1946); for each four-month period, the prominence areas for the separate classes are tabulated for each 10° of solar latitude. The areas for each latitude are summed and the average number of prominence units per day computed. These averages will be used to study trends throughout the sun-spot cycle.

For the years 1949 to 1952, a period during the last minimum in sun-

spot activity, the number of prominences that were intimately associated with spots varied from 21 per cent. of all prominences in 1949 to only 6 per cent. in 1952. When the direction of motion is considered, close to 94 per cent. were *A* prominences, i.e., 94 per cent. exhibited a downward motion of their luminous material.

There are, of course, some inherent errors in these measures. The surveys were taken whenever possible, some during periods of poor seeing, and some on days when clouds interrupted the observations. The present analysis does not include measures for the surveys taken on the days of poorest seeing or when the record was incomplete. In the remainder used for this investigation, the visible detail ranged from excellent to poor. Spicules can be observed and measured only when seeing is optimum, and the fainter portions of all prominences are lost on days of poor seeing. Hence all summations of areas must be regarded as too small.

Similarly, errors arise from the fact that some phenomena, such as surges, are so short-lived that they were not present when the survey photograph was made. Hence the totals I obtain for the *AS* and *AN* classes are more accurate than those for the *BS*'s and *BN*'s.

When measures are complete for a whole sun-spot cycle, the year-by-year analyses will be used to study variations of prominence types with solar latitude. These data should provide useful information about trends in the physical condition of the sun's atmosphere.

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SUMMER EVENINGS WITH THE STARS

By R. S. Evans

Victoria Centre

Summer Evenings with the Stars, the highly successful series of lectures and observational periods sponsored by the Victoria Centre, began in 1932. It is hoped that an outline of its history and development may suggest a similar enterprise to other Centres, who wish not only to recruit new members but also to rekindle interest and enthusiasm among their present members during the summer months, when observing conditions are usually at their best.

The Victoria Centre has been in continuous existence since 1914, with a membership that has varied in number between 40 and 143. The custom has been followed of holding monthly meetings from October to April, at which lectures have been given on literally hundreds of different topics in astronomy and related sciences by the members of the Centre or by scientists visiting the city.

Among those who helped in 1932 to organize the summer lecture series were the President of the Centre, Mr. P. H. Hughes, who continues to attend and maintain an interest in the activities of the Centre, the Secretary-treasurer, Mr. H. Boyd Brydon, whose name will be familiar to many readers through the articles he has contributed to the Journal, and the members of the Council. A special organization committee was appointed, consisting of Dr. J. A. Pearce (chairman), Mr. Brydon, Mr. Charles Hartley and Dr. F. S. Hogg. The purpose of the summer lectures was stated to be "to stimulate interest and knowledge of practical astronomy, to afford an opportunity for constellation study and for experience in observational work." The programme for 1932 provided for ten lectures to be given from July 12 to September 13, the speakers being, in addition to those members already named: Dr. C. S. Beals, Mr. James Duff and Dr. W. E. Harper. Included in the programme were such topics as The Celestial Sphere, The Summer Constellations, The Moon, Solar and Sidereal Problems, etc., titles that suggest what was and has been the primary aim of Summer Evenings with the Stars, namely to inform in basic astronomy those who are making their first acquaintance with the moon, the planets, the sun and the stars. From the beginning, opportunity has been given after each summer meeting for a period of observation out of doors, to learn to identify the constellations and the stars and to observe

objects through small portable telescopes belonging to members or to the Dominion Astrophysical Observatory.

It is of interest to record that the first meeting was held at the home of Mr. Brydon on Oak Bay Avenue, where the lecture was given in the garden and observations were made with the four-inch refractor Mr. Brydon had installed in an observatory on his grounds. So well attended was this meeting that it was necessary to hold subsequent meetings in the larger quarters of Victoria College, then located in Craigdarroch Castle.

The number of meetings of the summer course has varied between five and ten. Since 1935 one of the evenings has been set aside for a visit to the Dominion Astrophysical Observatory, where those attending the summer course are given the opportunity to view some object in the sky through the 72-inch telescope, and are told of the research work of the Observatory.

The topics of the speakers have followed the pattern set in the beginning—explanations and descriptions in the simplest possible terms of the basic facts of astronomy, instruction in the use of star maps and in acquiring a familiarity with the constellations, and experience in the use of a small telescope. The Centre is fortunate in having had at all times the enthusiastic co-operation of the staff of the Dominion Astrophysical Observatory. Many of the speakers have been members of the Observatory staff or, in some instances, astronomers visiting or working temporarily at the Observatory, but, as well, many of the speakers have been "amateur" astronomers of the Centre.

The meetings in recent years have been held in the auditorium of Victoria College, now located on Landsdowne Road, where the spacious grounds, removed from the troublesome city lights, provide an ideal location for the observation period that follows each meeting. Some four or five telescopes belonging to the members are set up, and as well, supervised constellation study is carried on with binoculars and with unaided eye.

The registration at Summer Evenings with Stars has varied, reaching a high point of 199 in each of the years 1952 and 1953, exclusive of members of the Centre. The latter may attend the summer meetings free, whereas a charge of $1.00 has been made for non-members, to defray the cost of newspaper advertising and printing of programmes, and of star maps and booklets that are given to each one attending. Out of this registration, each year the Centre has acquired an average of ten new members, who join for the purpose of continuing and broadening their knowledge of astronomy. It is interesting to note, however, that the

summer lectures have proven to be so enjoyable and instructive in themselves that there have been many instances of a non-member registering for them in several successive years.

The Victoria Centre has been fortunate in having been given free advertising for the summer lectures through the generosity of two business firms, the B.C. Electric Company and T. Eaton Company. For many years one or the other of these firms has donated, for the week preceding the meetings, the entire space of one street-level show window, and has given window-dressing assistance to the Centre in setting up a display of telescopes, maps and photographs describing the activities of the Centre. These windows have attracted a great deal of attention and much favourable comment, and we feel that they are principally responsible for the success of Summer Evenings with the Stars.

For the first summer since 1932, the meetings were not held in 1957. In their place, and at the invitation of officials of Victoria College, a short series of lectures on astronomy was offered as a non-credit course for teachers attending the Summer School of the College. These meetings were open, as well, to members of the Centre. At this writing, it is not known what form the summer activities will take in 1958.

It has been a wonderful experience to have participated in Summer Evenings with the Stars, and it is our hope that a similar programme may be adopted at other Centres to stimulate interest in astronomy and to satisfy the present ever-increasing thirst for knowledge in this and related sciences.

IMPULSIVE AND LONG-ENDURING SUDDEN ENHANCEMENTS OF SOLAR RADIO EMISSION AT 10-CM. WAVE-LENGTH*

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Abstract

The two basic types of simple 10-cm. enhancements of solar radio emission are described and related to suggested non-thermal and thermal mechanisms of emission.

Solar flares release various kinds of energy within the short span of a few minutes and many branches of science will be called upon to give us a complete understanding of the phenomena. In the field of radio astronomy, sudden enhancements of solar emission—the so-called bursts of solar radio noise—have been observed at various frequencies and it is apparent that there is a close association between many of these enhancements and the complex flare phenomenon. At the Radio and Electrical Engineering Division of the National Research Council in Ottawa, about 2390 solar noise bursts have been recorded since regular observations were started in 1947. Of this total, 700 were observed in the years 1947–55, 675 in 1956 and 1015 in 1957. The early records, 1947–55, were taken at a wave-length of 10.7 cm., while the addition of a second radiometer has made possible the simultaneous recording of solar events at wave-lengths of 10.7 and 10.2 cm. during 1956 and 1957. It is interesting that no significant difference in the form of the bursts has been observed on these two wave-lengths and that within the present accuracy of recording only a few examples of noticeable differences in burst intensity have appeared.

Simple Bursts. The relative simplicity of burst structure and the infrequency of occurrence of the 10-cm. bursts have been noted before (Covington and Medd, 1949) and are in great contrast to the complexity and great abundance of bursts in the metre wave-length region. The most obvious feaure of the 10-cm. bursts is the large number of bursts of simple structure, that is those which rise to one maximum and return to the preburst level. As an example of their frequency of occurrence, it is noted that approximately 90 per cent., that is 600, of the total number of bursts

*Part of material presented at U.R.S.I. Conference held in Boulder, August 1957.

recorded for 1956 were of this class. The remaining 10 per cent. have a complex structure with, for the most part, two or more peaks.

The significant primary features of a simple burst are the intensity, the duration and the rate of rise and fall. The first two of these cover a wide range—the intensity from values barely discernible above receiver noise to thousands of units of flux; the duration from a fraction of a minute to several hours. If a scatter diagram is plotted of intensity against duration, with a dot for each simple burst, an interesting feature is noted which is illustrated in figure 1, where such a scatter diagram is shown for the simple bursts occurring in the year 1956. The clustering of dots is not wholly random but shows a well developed two-pronged distribution which indicates the existence of two types of simple bursts that are basically different

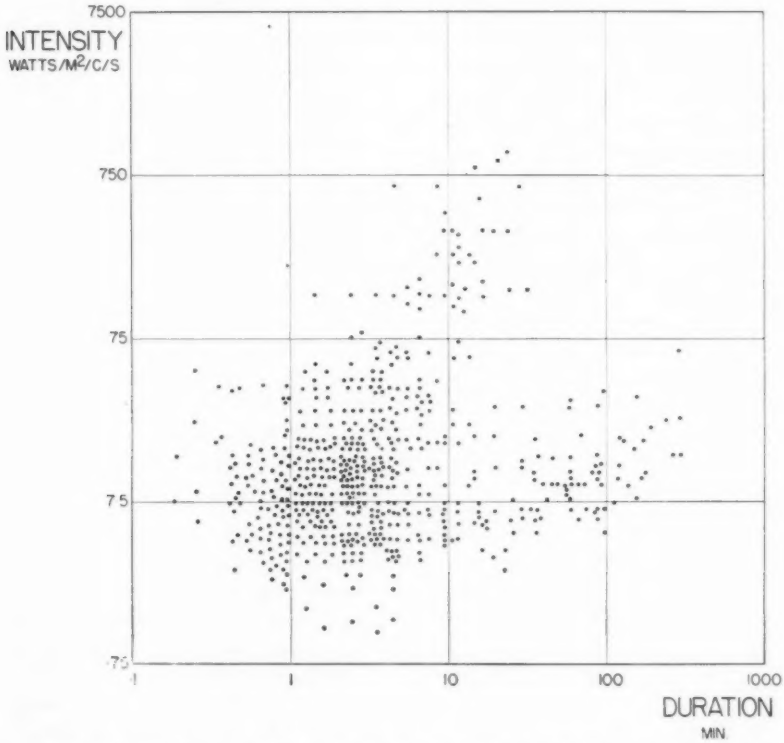

FIG. 1—Scatter Diagram of Simple Bursts for 1956. Log of intensity versus log of duration.

—the one an impulsive burst of relatively high intensity and short duration, the other a long-enduring burst of relatively low intensity.* In the region of moderate intensity and duration, a random scatter is observed where both types presumably appear together. Examination of the rates of rise and fall for the simple bursts shows that in general the rate of rise is greater than that of the fall. The ratio of the time taken to reach maximum to that of the total duration shows a variation from 0.1 to 0.5 with an average of 0.25 for the impulsive and an average of 0.4 for the long-enduring bursts.

Combinations of Simple Bursts. In the majority of cases the impulsive and the long-enduring bursts are relatively well isolated from one another on the records but at times the bursts may appear in various types of combination. These combinations happen more frequently than could be expected from any random association and will be of significance for studies of flare mechanisms.

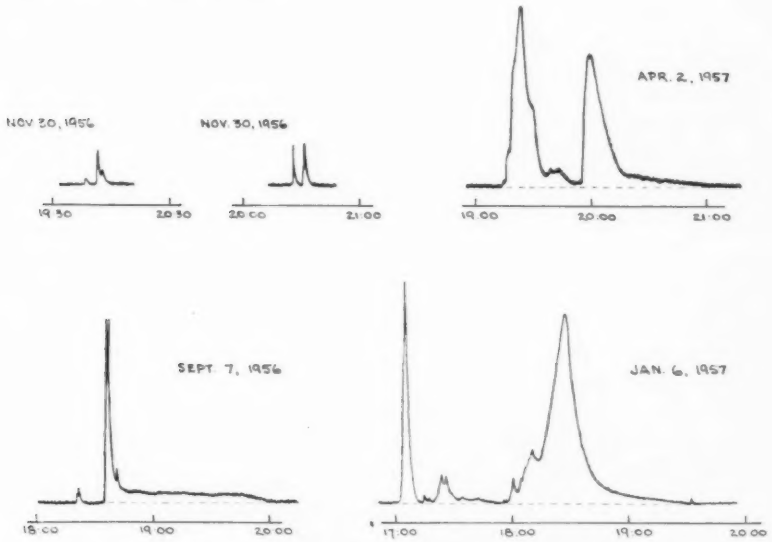

FIG. 2—Groups of Bursts. Nov. 30, 1956: Simple, Complex. Nov. 30, 1956: Simple, Simple. Apr. 2, 1957: Complex, Simple, Post. Sept. 7, 1956: Simple, Complex, Post. Jan. 6, 1957: Simple, Complex, Post, Simple, Simple.

*formerly called "gradual rise and fall."

One type of combination of events often found is a group of two or more impulsive bursts and is illustrated in figure 2. It is possible that the complex burst with its two or more distinct peaks may be the result of simple impulsive bursts occurring in more rapid succession than that which is seen in the group phenomenon. This supposition gains weight when the complex bursts are plotted on the simple burst scatter diagram since the grouping of the dots is found to lie about a line parallel to the line of impulsive bursts but displaced in the direction of greater duration.

Another type of combination in which impulsive bursts appear superimposed upon a long-enduring burst is illustrated in figure 3. Such cases are not classified as a complex phenomenon but rather as bursts of simple structure of different duration. An event which bears a close similarity to this type is an impulsive burst which does not return immediately to the

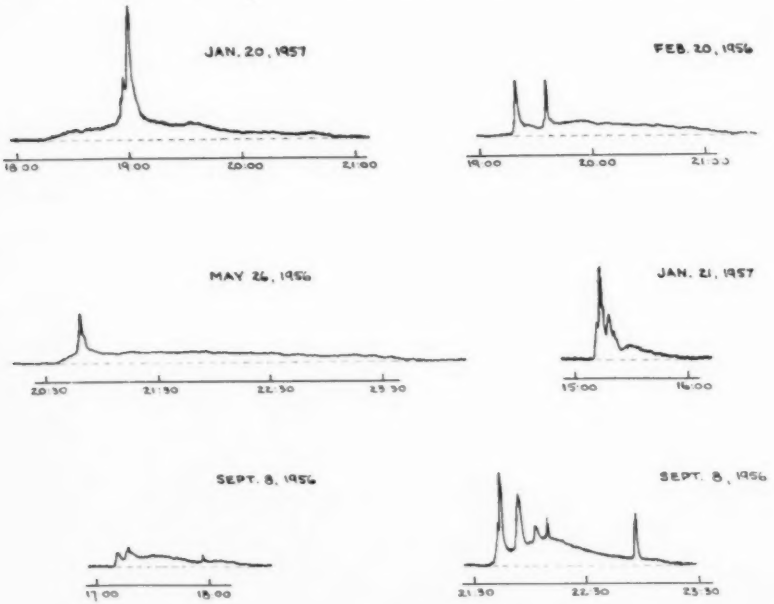

FIG. 3—Impulsive bursts superimposed upon long-enduring bursts. Jan. 20, 1957: Long-enduring, Complex. Feb. 20, 1956: Long-enduring, Simple, Post, Simple. May 26, 1956: Long-enduring, Complex. Jan. 21, 1957: Long-enduring, Complex. Sept. 8, 1956: Long-enduring, Complex, Simple. Sept. 8, 1956: Long-enduring, Simple, Simple, Simple, Simple, Simple.

pre-burst level but is followed by a long-enduring after-effect of moderate intensity called a post-burst increase. In respect to the duration and intensity, the post-burst feature may be regarded as a long-enduring burst which commences at the same time as or during the impulsive burst. However, at the present time no attempt has been made to treat this as two separate events.

Other Burst Features. The impulsive and the long-enduring bursts, singly and in their various combinations, make up the major features of most of the observed 10-cm. bursts. However, a description of the bursts observed at this wave-length would not be complete without mention of a secondary phenomenon which is sometimes observed. This feature may be described as a small fluctuation or fluctuations which appear superimposed upon the main event (e.g. figure 2, bursts—Apr. 2, 1957 and Jan. 6, 1957). If the fluctuation becomes too intense the event would generally be classified as a complex burst. It is significant that frequently fluctuations are completely absent and that one observes only the smooth rise and fall of either of the two basic burst forms. Another type of burst variation, a gradual diminution of flux occurring after an impulsive burst, was reported in detail for May 19, 1951, and reveals the significance of the absorptive process rather than the emissive process (Covington and Dodson, 1953). This infrequent type of event was observed a second time on March 1, 1956, and again was associated with a dark flocculus lying over part of the bright flare region (Dodson).

Flare Association. Previous analysis of the time relationships of the variations of the intensity of the 10-cm. burst with the variations of the light emitted from ionized hydrogen atoms (Dodson, Hedeman and Covington, 1954) revealed that the impulsive bursts tend to commence simultaneously with the hydrogen brightening, to reach peak intensity rapidly while the optical brightening is growing in intensity, and to return to normal while the light output is at a peak. Although the long-enduring bursts commence with the brightening of the flare, the peak emission and the termination tend to show considerable delay with respect to the corresponding features of the optical brightening. There is also a strong probability, almost a certainty, that every 10-cm. burst is associated with some flare; but that conversely, a smaller number of significant flares have no corresponding emission at 10 cm. These properties of the 10-cm. burst are significant for any explanation regarding the emission of radio noise bursts and the generation of the energy of flares.

Suggested Physical Mechanism. The obvious difference between the impulsive and the long-enduring bursts suggests that these bursts reflect the nature of different physical processes of generating energy within the flare region. The ejection of particles and the emission of ultra-violet light radiation are perhaps the two most fundamental processes indicated by geophysical studies of the aurora and the sudden interruption of short-wave radio circuits. It is tempting to suggest that the impulsive burst is generated by non-thermal processes related to the outward passage of highly energetic particles through the ionized atmosphere in the immediate vicinity of the flare, while the long-enduring burst is generated by thermal processes related to the physical characteristics of this same region. The slowly varying component of solar flux—that is, the component of microwave flux which varies in close association with the sunspots, and apparently more closely with the bright regions of hydrogen or calcium—has been interpreted as the thermal emission from an overlying region in the hot solar corona and could be considered as a member of the class of long-enduring bursts. Although the great duration of several months and the intensity of several hundreds of flux units tend to make the point representing the emission from a single coronal condensation lie on a hitherto unoccupied part of the scatter diagram, it does, however, fall on the general trend of the cluster of points which represents the long-enduring bursts. This suggests that the long-enduring bursts and the slowly varying component of solar flux are of the same class and that the same process of emission is involved. In this case, the long-enduring burst could be considered as a manifestation of a short-lived "radio sunspot." The varied association of the simple impulsive superimposed upon the simple long-enduring burst, if originating in the same solar region, should be of great aid in revealing the time of occurrence of particle emission in the lifetime of an active solar region. It is certainly desirable to pursue further the analysis outlined here and to find other features, either of flare or burst, which will aid in these matters.

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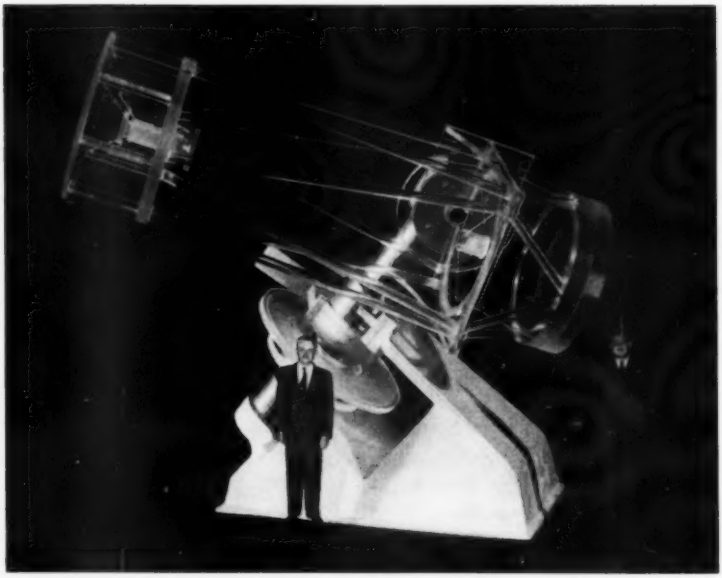
A NEW 48-INCH TELESCOPE FOR THE DOMINION ASTROPHYSICAL OBSERVATORY

At Victoria it was concluded some years ago that much of the research work being done at the Observatory could best be continued and extended by the provision of a second telescope to supplement the observational capabilities of the 72-inch reflector. Plans were therefore made for a 48-inch reflector and discussions carried on with authorities of the Department of Mines and Technical Surveys. Negotiations have culminated in the placing of an order for the telescope and the beginning of construction of the new dome building.

The order for the 48-inch reflecting telescope was placed with Sir Howard Grubb Parsons of Newcastle-upon-Tyne, England, in September 1957. Estimated delivery date is the first half of 1961. The general design and specifications of the telescope were laid down by the Observatory, but the detailed design and engineering are the responsibility of the manufacturers. The mounting is to be of a modified English type, the telescope being mounted on one pier only, and the polar axis being truncated just above its intersection with the declination axis. (See the accompanying photograph of a model constructed in the Observatory shop). There will be three f/18 foci, one at the usual Cassegrainian position, and two near the intersection of the polar and declination axes. There will also be an f/30 coudé focus. Provision is made for possible future work at the prime focus; the 48-inch mirror has a focal ratio of f/4.

It is planned that the telescope will have a photoelectric photometer mounted permanently at one f/18 focus. Spectrographs and experimental equipment may be placed at the other two f/18 foci. Work at the coudé focus will be mainly spectrographic. A coudé spectrograph modelled on the principles of the highly successful instruments at Mount Wilson and Palomar will be built. The f/30 beam will be reflected horizontally in an easterly direction six feet short of its focal point, so the coudé room will be horizontal rather than, as usually, inclined at the angle of latitude.

The dome building will consist of a 32-foot diameter dome above a nine-foot-high ground floor containing the 25 ft. by 24 ft. coudé room and other usual facilities. The dome will have a shutter of the type used on the dome of the Lick 120-inch telescope. The building was designed by the engineering firm of A. B. Sanderson and Co., Victoria and Vancouver, under authority of the Department of Public Works. This Department, after calling for tenders, has recently let the contract for construc-



tion to the Commonwealth Construction Co. of Vancouver, and actual work was started on February 17, 1958. The building is situated several hundred yards to the north of and about at the same altitude as the dome of the 72-inch reflector. It is anticipated that the building will be completed within the year. This will leave adequate time for construction of the spectrograph, photometer and other equipment, in the Observatory shop before the arrival of the telescope.

CANADIAN SCIENTISTS REPORT-XII

METEOR SPECTROSCOPY WITH TRANSMISSION DIFFRACTION GRATINGS*

By Ian Halliday

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Earlier articles in this series have reviewed a number of fields of astronomical research in which Canadian scientists have special interests. This paper deals with another field, that of meteor spectroscopy, in which Canadian observations have played a leading role. Of the 214 meteor spectra in existence at the end of 1956, 45 per cent. were secured in Canada. Other major contributors to this field have been the United States (29 per cent.), the Soviet Union (16 per cent.), Great Britain (5 per cent.), and Czechosolvakia (4 per cent.). The initiation of the various Canadian programmes for obtaining meteor spectra has been due almost entirely to the efforts of Dr. P. M. Millman, formerly of the Dominion Observatory, who has made meteor spectroscopy a main interest for more than twenty-five years.

Meteor spectra may be secured by mounting either a prism or a transmission diffraction grating in front of a conventional camera or an astronomical telescope. The early spectra were all secured with prisms but recently the emphasis has shifted to gratings, particularly in the Canadian and United States programmes. Diffraction gratings are expensive, but the spectra they produce have nearly linear dispersion, whereas prisms give good dispersion at the blue end of the spectrum but very low dispersion in the red. With gratings a convenient range of dispersions may be obtained with suitable combinations of gratings and cameras. High dispersion requires thick glass prisms which introduce problems in mounting and a considerable loss of light by absorption in the glass. Our discussion will be confined to meteor spectrographs employing gratings.

Diffraction Gratings. The theory of diffraction gratings may be found in any text-book on optics. Basically a grating consists of a great number

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of evenly-spaced, accurately parallel rulings or grooves, generally between 2,000 and 30,000 per inch and the dispersing properties result from diffraction at the ruled surface. The gratings employed in meteor spectroscopy are generally *replica* transmission gratings. These are made by depositing a thin film on an original or master grating. When the film is removed and mounted on glass it has become a copy of the master grating.

A grating produces several complete spectra or *orders*. Some light is not diffracted and when focussed by the camera forms a conventional photograph of the source or *zero order*. On both sides of this a series of complete spectra is formed, with the blue ends nearer the zero order. Thus we have two first-order spectra, two second-order spectra, and so on. By ruling the grating with a diamond point shaped to produce an asymmetrical groove, the grating may be given a *blaze*, which means that the diffracted light is concentrated in one part of the spectrum. The gratings employed by the Dominion Observatory for meteors are blazed to give maximum intensity in the first order and the blue end of the second order on one side.

Description of Meteor Spectographs. The meteor observatories operated by the Dominion Observatory at Meanook and Newbrook, Alberta, currently employ seventeen meteor spectrographs with diffraction gratings. This is probably the largest concentration of such equipment associated with any single research group. A description of the various cameras and gratings at these observatories will illustrate the fundamental points involved in meteor spectroscopy.

In laboratory spectroscopy a narrow slit is usually illuminated by the radiation under study and each wave-length is made to produce an image of the slit, or spectral line, after dispersion by the prism or grating. For meteors this arrangement is impossible because the position of the source (the meteor) is unpredictable. Fortunately the meteor itself provides a suitable alternative, for its path in the sky is a narrow line. Each of the bright lines which appears in a meteor spectrum is a photograph of the meteor in the light of one particular radiation of one chemical element. It is worth mentioning that in the case of a meteor with a wide luminous trail, or one which broke into widely separated pieces, the spectral lines would also become wide or multiple.

The grating for a meteor spectrograph is mounted in a metal cell which fits tightly over the lens of the camera. The delicate surface of the grating is put on the inside, facing the lens, and the glass of the grating blank is separated from the metal cell by thin pieces of cork. A cover protects the outer surface of the grating when the camera is not in use.

Most of the spectrographs at Meanook and Newbrook are provided with rotating shutters, mounted with the blades a small distance above the gratings. The meteor spectra are thus chopped into segments from which velocity data for the meteor may be obtained just as for conventional meteor cameras. The shutters also provide an opportunity to photograph the spectrum of the luminous wake behind very bright meteors by occulting the meteor itself for part of the cycle leaving an unexposed area which makes it possible for the camera to record the wake after the shutter has reopened. A further practical advantage of shutters is evident. If sky fog would normally limit a given camera to exposures of half an hour then a shutter which occults the sky half the time will allow the exposure time to be lengthened to an hour, with a considerable saving in cost of plates and film.

Some of the meteor spectrographs are converted war-time aerial cameras. Table I lists properties of the five different camera types and five different gratings employed. At present there are six different combinations of gratings and cameras. The aerial cameras are Williamson F24 cameras manufactured in Britain, and American K19 cameras with Kodak Aero-Ektar lenses, modified to use glass plates instead of film. The "short focus" cameras employ extremely fast lenses manufactured by Wray Optical Works, England, and they are mounted in a commercial camera body. A quartz lens and quartz grating are combined for ultra-violet spectroscopy in a camera designated UV. A "long-focus" telephoto lens has also been mounted to form a spectrograph.

Successive rows in Table I show the number of each type of camera in operation, the focal length, f; the ratio of focal length to lens diameter, f/d. The F24 cameras employ roll film, 5½ inches by 56 feet, and the short-focus cameras use 100 foot rolls of 35 mm. film. The other cameras use 8×10 inch plates. To obtain a fairly large field the long-focus camera has four separate 8×10 plateholders arranged to form a rectangle about 17×21 inches in size. Part of the field is thus lost where the plateholders touch each other. The useful field of each camera is shown in the next row.

Some idea of the relative efficiency of the cameras in photographing meteors may be obtained in the following way. The total number of meteors photographed by a spectrograph depends upon the magnitude of the faintest meteor which can be recorded and upon the area of sky covered. For a moving point such as a meteor, the speed of the camera is proportional to the area of the lens and inversely proportional to the focal length (since the trailing speed of the image across the plate increases with the focal length). The important quantity is thus d^2/f, if the camera is in ideal condition, not d^2/f^2 which would apply to an extended

object. The values of d^2/f show that the UV camera is the slowest. In the next row the ratios of d^2/f have been converted to show the number of stellar magnitudes, Δm, that each camera should reach fainter than camera UV will reach. According to Millman and Burland (Millman 1957) in the visible range there are 3.7 times more meteors of a given magnitude than meteors one magnitude brighter. Accepting this value, the total number of meteors each camera could photograph is proportional to the values of T in the next row.

TABLE I

DESCRIPTION OF METEOR SPECTROGRAPHS

Camera	F24		K19	short focus	UV	long focus
No. in use	9		3	3	1	1
Focal length, f, in.	8.0		12.0	2.5	8.0	36.0
Focal ratio, f/d	2.9		2.5	0.71	3.5	6.3
Useful field, sq.deg.	1200		1600	250	1250	750
d^2/f	0.97		1.92	4.93	0.66	0.90
Δm	0.42		1.16	2.18	0	0.34
T	1.8		4.8	13.4	1.0	1.6
N	1.7		6.0	3.3	1.0	1.0
$1/a$, grooves per mm.	200	400	300	80	300	300
λ_0, in A.	5000	5000	6000	6000	3500	6000
Disp., A./mm.	246	123	109	1953	164	36

Consider two cameras identical in all respects except that one camera covers twice the field of the other. Suppose they are pointed to the sky so that the smaller camera covers the left half of the field of the other camera. Let there be x meteor trails entirely within the left half of the larger field. There will then also be x trails within the right half. Let there be y trails which cross the dividing line between the two halves. The smaller camera will then record at least part of $x + y$ trails, and the larger camera $2x + y$ trails, i.e. the smaller camera records more than half as many trails as the larger one although more of these will be photographed over only part of their length. For a circular field of radius r and meteor trails of length s the number of photographs will be proportional to $(\pi r^2 + 2sr)$. The average length of trail, s, for 28 meteor spectra photographed at Meanook and Newbrook is 7.3 degrees. The relative number of meteors expected per camera, N, where $N = T(\pi r^2 + 2sr)$, are given in the next row. They have been normalized to 1.0 for the long-focus and ultra-violet spectrographs which have the lowest expectations. The inclusion of the correction term, $2sr$, has not changed any value of N by as much as 20 per cent.

The approximate constancy of the yield from such widely different cameras is perhaps surprising. The K19 cameras have the highest expecta-

tion because they combine good speed with an exceptionally large field. The number of spectra obtained also depends on the efficiency of the grating. In general a coarse grating (relatively widely-spaced rulings) will be more efficient than a grating giving high dispersion.

The next two rows of Table I show the number of rulings per mm. on the grating, $1/a$, where a is the grating spacing, and the wave-length in the first order spectrum, λ_b, for which the blaze gives maximum efficiency. Two combinations are in use at present with the F24 cameras and a third was formerly used with them. The gratings were all produced by the Bausch and Lomb Optical Co., Rochester, N.Y.

The fundamental relation for a diffraction grating is

$$n\lambda = a(\sin i + \sin \theta) \tag{1}$$

where n is the order of the wave-length λ in question, and i and θ are the angles of incidence and diffraction, respectively. By differentiation,

$$n\, d\lambda = a \cos \theta\, d\, \theta. \tag{2}$$

Now $\tan \theta = x/f$ where x is the linear distance from the axis in the focal plane, in the direction of the dispersion. Differentiating,

$$\sec^2\theta\, d\theta = dx/f. \tag{3}$$

Substituting for $d\theta$ in (2) and re-arranging, we obtain the general expression for the dispersion,

$$\frac{d}{dx} = \frac{a \cos^3\theta}{n\ \ f}. \tag{4}$$

The dispersions at the centre of the field ($\cos \theta = 1$) are shown in Angstroms per mm. in the final row of Table I for the first order spectrum, i.e. $n = 1$. A smaller number indicates higher dispersion. Away from the centre of the field the dispersion increases as $\cos^3\theta$ decreases. At a distance of 25 degrees from the centre the dispersion is about 30 per cent. greater than shown in the table. At the time of writing the long focus camera has been in operation only a few months and has not yet photographed a meteor spectrum. The highest dispersion obtained to date is the blue end of the second order spectrum of a meteor photographed with one of the K19 cameras. The dispersion is 48 A./mm.

Some of the meteor spectrographs may be seen in figure 1 which shows three of the spectrographs at Meanook. The rotating shutters are 30 inches in diameter and the ratio of occulted to open sectors is 2:1. In operation the shutters are driven by commercial half-inch drills.

Several different emulsions are used on the meteor spectroscopy programme. The F24 cameras use either Kodak Tri-X Aerial Reconnaissance

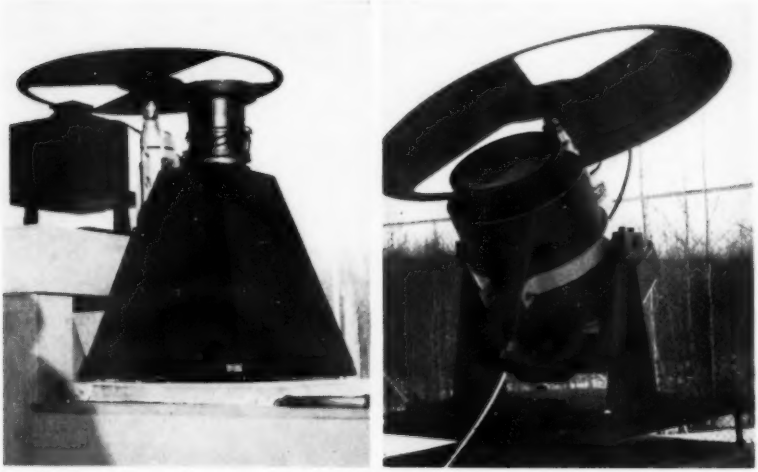

FIG. 1—Meteor spectrographs at Meanook. *Left*, ultra-violet and long-focus spectrographs mounted beneath a single shutter. *Right*, one of three K19 spectrographs showing grating cell from above.

film or Kodak Infrared Aerographic film in rolls 120 exposures in length. The rolls are calibrated for photometric purposes with a rotating sector in front of a Hilger single-prism quartz spectrograph. The UV camera employs a fast blue-sensitive emulsion, Kodak spectroscopic 103-O plates. The plates are calibrated with a quartz step-wedge used with an ultraviolet filter. The K19 and long focus cameras use Kodak Spectroscopic I-D plates, while the same fast, panchromatic emulsion is supplied on 35 mm. film for the short focus cameras. Calibration apparatus for these cameras has not yet been completed.

Observational Aims. The development of the present array of meteor spectrographs has been closely related to progress in the study of meteor spectra themselves. During a period of 20 years up to about 1953 strong meteor spectra were obtained with dispersions between 200 and 800 A./mm. Study of these spectra showed the desirability of constructing spectrographs with higher dispersion, for wave-length measures, line identifications and photometry are all made difficult by the general blending of two or more spectral features with low dispersion. As an example, there are two lines of neutral iron at 4375.9 and 4383.5 A. Normally the line at 4383.5 A. is much the stronger of the two, but under

certain conditions the situation may be reversed. With low dispersion the two lines are blended, but they were easily resolved in the second order of a spectrum photographed with one of the K 19 spectrographs. A few meteor spectra were so strongly over-exposed at low dispersion that they would clearly have given excellent spectra with slower instruments of high dispersion. It is for this reason that the Dominion Observatory has added the K19 cameras and particularly the long focus camera to the instruments at Meanook. It is worth noting that the identification of lines in meteor spectra is still uncertain to the extent that for at least two atoms or ions several lines are claimed by the investigators at one institution (and in at least two spectra) whereas the same atom or ion has not been identified at all in spectra secured elsewhere. This type of conflict could be settled by a single high-dispersion spectrogram.

There is also increasing interest in the spectra of fainter meteors. Nearly all existing spectra are for meteors which were at least as bright as Sirius, the brightest star in the sky. In an attempt to obtain the spectra of fainter meteors one must be prepared to sacrifice dispersion for extreme speed. The study of the spectra would probably then be limited to general trends and relative intensities of the strongest features but enough spectra might be secured to make available a statistically significant group. The short focus cameras will reach to considerably fainter meteors than any of the others at Meanook or Newbrook, and they are equipped with the most efficient gratings as well. The dispersion, of course, is extremely small. Fast, large-aperture cameras, such as the Super-Schmidt telescopes or conventional Schmidt telescopes, have a great advantage here, because they have very large values of d^2/f. Gratings are not yet available in large enough sizes for such instruments, but a few good spectra of faint meteors have been secured with the 18-inch Schmidt on Palomar Mountain, equipped with an objective prism (Russell, 1957).

Observational Problems. Certain problems encountered in observing with meteor spectrographs are of interest. The average exposure time is usually between 20 minutes and an hour, although the short focus cameras fog so quickly from skylight that an intervalometer is used to advance the film automatically every one to five minutes. The brighter stars trail across the field and produce spectra which may occupy a considerable portion of the field. The stellar spectra cause confusion if they overlap a meteor spectrum but are useful in establishing the spectral sensitivity of the instrument from the known energy distribution for the stars. Care must be taken in this procedure since the blaze of the grating, which affects the observed energy distribution greatly, is itself dependent on the angle

of incidence of the light on the grating. Guided cameras pick up a great many star spectra which confuse the field much more than a few trailed star spectra with unguided cameras. A rotating shutter appreciably reduces the number and intensity of the stellar spectra.

Each spectral line in a meteor spectrum is parallel to the zero-order image but the lines are generally not perpendicular to the dispersion. For shower meteors an attempt is made to keep the spectral lines nearly perpendicular to the dispersion by having the rulings of the grating lined up so that if they are projected into the sky they are parallel to the expected direction of shower meteors. Sometimes cameras must be moved to avoid cloud, aurora or moonlight and there is not always time to readjust the orientation of the gratings. There is a tendency for sporadic meteors to be perpendicular to the horizon rather than parallel to it, so on non-shower nights the gratings are usually set with the rulings in a vertical plane.

A meteor on the axis of the camera will have its zero-order image in the centre of the plate and its strong spectrum off to one side. With high dispersion these displacements become considerable, especially for the blue or violet parts of the second order. For a wave-length of 4200A. and a grating with 300 rulings per mm. the second order will be nearly 15 degrees away from the zero order, or more than 9 inches on the plate for the long focus camera. To obtain a given order of the spectrum near the centre of the film the meteor must appear off to one side of the camera field and for shower meteors the grating should be aligned accordingly. In mounting the grating on the camera it is important to know on which side of the zero order the strong orders will appear. The operator looks through the grating with the ruled surface toward his eye and observes that the strong spectrum from a light is, say, to the left of the zero order. This is then called "strong order left" (when the rulings are vertical) and a mark is put on the grating cell for reference purposes. The camera is then set for meteors as shown in figure 2. To obtain spectra near the centre of the field, where optical conditions are usually best, the meteors must appear some 10 to 15 degrees to the *right* of the apparent direction of the camera. The *apparent* direction from which the spectrum comes is seen to be to the *left* of the direction to the meteor, as was observed in looking through the grating.

The field of a meteor spectrograph is effectively increased by the grating, for if the field of view of the camera without the grating is 40 degrees, and the angular separation between the useful ends of the spectrum is 15 degrees, then there is a range of 55 degrees in which the

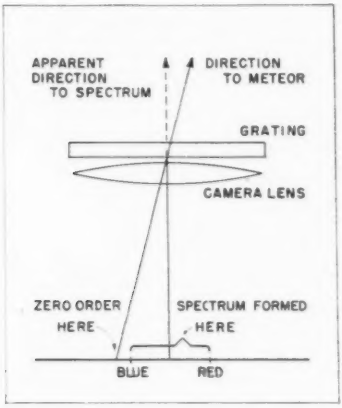

FIG. 2—Sketch showing displacement of meteor from its spectrum.

meteor can appear and still have some part of the spectrum in the field. For extremely bright meteors the field is sometimes greatly increased in this way for parts of the orders on the side opposite to the grating blaze may be picked up.

A further complication in meteor spectroscopy arises from the unpredictable location of the source within the field. The source may be off to one side as we have seen above, but it is usually displaced in a direction *along* the rulings as well, i.e., no part of any order passes through the centre of the field. It may be shown that in this case the diffracted light for a point on the trail lies on a cone whose axis is parallel to the grating rulings. The intersection of this cone by the focal plane of the camera is a hyperbola, with the vertex the closest point to the centre of the field. For spectra near the edge of the field this curvature is sometimes quite obvious and introduces problems in measuring a long spectrum.

No discussion of meteor spectroscopy would be complete without some mention of the patience required by the observer. Bright meteors are rather infrequently observed. To obtain a good meteor spectrum a bright meteor must appear in the field of the camera and, preferably, it should travel at a large angle to the dispersion. While more spectra will be secured during the peak nights of shower activity than at other times the over-all average is about one meteor spectrum per 100 hours of observation per camera.

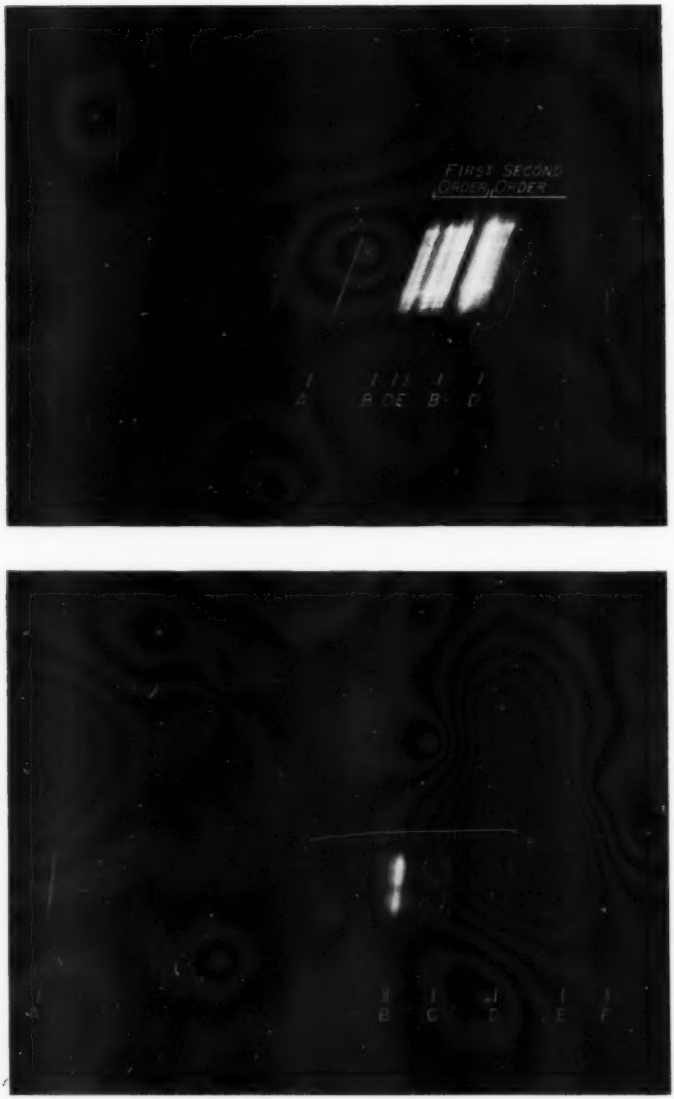

FIG. 3—*Above*, Geminid meteor photographed at Meanook, December 14, 1954, $4^h\ 18^m$ U.T. *Below*, Sporadic meteor photographed at Newbrook, August 8, 1957, $6^h\ 30^m$ U.T. Both meteors moved from top to bottom.

Sample Spectra. Many of the points discussed above are illustrated by reference to the two spectra shown in figure 3. The first (above) is the spectrum of a Geminid meteor photographed close to its radiant. The segments from the rotating shutter are very short because of the low angular velocity in this case. The instrument was an F24 camera at a time when the 80 line per mm. gratings were mounted on them. Note the prominent first order and the blue end of the second order due to the blaze of the grating. Parts of the weak orders to the left of the zero order are also visible. At the right are the trailed spectra of Castor and Pollux. A single segment of the meteor spectrum is slightly convex upwards due to the hyperbolic form of the spectrum.

The lower spectrum is that of a sporadic meteor photographed without a shutter with an F24 camera and one of the 400 line per mm. gratings. The dispersion is about 5 times that of the top spectrum. Only the zero order and first order were within the camera field. On the original negative many weak lines can be measured which tend to be blended on low dispersion such as in the top spectrum. A few of the stronger features are labelled and identified in Table II. The magnesium green feature is

TABLE II

Identification of Strong Features

Feature	Name	Atom or Ion	Wave-lengths
A	Zero order		
B	H and K	Ca II	3968.5, 3933.7
C		Mg II	4481.2
D	Magnesium green	Mg I	5167.3, 5172.7, 5183.6
E	Sodium D	Na I	5890.0, 5895.9
F		Si II	6347.1, 6371.4

clearly resolved into two of its three components on the original negative of the high dispersion spectrum. The inclination of the lines to the dispersion is evident, but both these illustrations are favourable cases in this regard.

The Dominion Observatory will continue to photograph the spectra of meteors with the equipment described above and with such improved instruments as may be available in the future. In this way we hope to extend our knowledge of meteors themselves and the manner in which they interact with the upper atmosphere during their brief luminous display.

References

Millman, P. M. 1957, *Jour. R.A.S.C.*, vol. 51, p. 113.
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NOTES FROM OBSERVATORIES

DAVID DUNLAP OBSERVATORY, RICHMOND HILL

Tests are being made of an integrating exposure meter recently installed in the spectrograph of the 74-inch telescope. This device, constructed in the Observatory workshop by Gerald Longworth and Frank Hawker, will eliminate guesswork in the photographing of stellar spectra.

The 74-inch mirror was re-aluminized in May by Gerald Longworth. This is now being done every two years.

Dr. A. G. W. Cameron of Atomic Energy of Canada visited the Observatory in February, conducting several seminars on the topic of Nucleogenesis in Stars.

Dr. J. B. Oke has left the Observatory staff to join the staff of Mount Wilson and Palomar Observatories as Assistant Professor at the California Institute of Technology. His colleagues here, while regretting his leaving, wish him continued success in his career.

Replacing Dr. Oke on the staff will be Dr. Sidney van den Bergh, formerly of the Perkins Observatory, Delaware, Ohio. Dr. van den Bergh, originally from the Netherlands, received his scientific training at Leiden, Princeton, Ohio State and Göttingen Universities.

Dr. Helen Hogg of the Observatory staff was honoured in June when her Alma Mater, Mount Holyoke College, conferred on her the degree of Doctor of Science, *honoris causa*.

Summer assistants at the Observatory this year include Miss Külli Milles and Messrs Helge Mairo, David Sher, William Greig and Peter McConkey, all students at the University of Toronto.

Public interest in the Saturday evening visiting periods conducted by the Staff and by volunteers from the Toronto Centre of the R.A.S.C. has increased to the point where the reservations list is usually filled several weeks in advance.

JOHN F. HEARD

METEOR NEWS

By Peter M. Millman
National Research Council, Ottawa

THE I.G.Y. VISUAL METEOR PROGRAMME—PROGRESS REPORT NO. 2

Progress Report No. 1 (1) listed all the meteor observations on this special programme which were received in Ottawa up to Oct. 15, 1957. These totalled 18,885 meteors recorded in 8,743 ten-minute observing intervals.

Since then, up to April 15, 1958, we have received observations of an additional 14,997 meteors, recorded in a total of 7,722 ten-minute observing intervals. These are summarized here in Table I, which contains all new material and does not include any of the meteors listed in the previous report. The overall mean hourly rate for the observations in this second report is 11. As pointed out previously this number is not particularly significant until the observations have been analysed on the basis of time of year, time of night and number of observers working.

The listing in Table I follows that of the previous progress report. In the first column is found the location of the observing station, followed in the second column by the name of the individual who has communicated the observations to headquarters. The stations have been listed alphabetically in each of the two parts of the table. Those appearing in the first part are stations from which observations were included in Progress Report No. 1. Those in the second part appear here for the first time. The last four columns of the table are self-explanatory, giving the number of nights worked, the total number of 10-minute intervals on which observations were carried out, the number of meteors recorded and the average number of observers (including timekeeper) active at one time.

In this report we welcome the addition of observations from Brazil, India, Japan, New Zealand, the Philippines and South Africa. At the 108 stations listed in the table, 315 observers, plus three additional groups of unspecified size, took part. Among the groups Ottawa #1; Kanaya, Japan; New York, N.Y. #4; and Rio de Janeiro, Brazil #3 observed over the largest number of 10-minute periods. On this same basis the single observers A. Kamo at Wakayama, Japan, and T. J. Bolenski at Beacon Falls, Conn., have made outstanding records.

SUMMARY OF OBSERVATIONS RECEIVED FROM OCTOBER 15, 1957, TO APRIL 15, 1958, ON THE SPECIAL I.G.Y. VISUAL METEOR PROGRAMME

Location	Name	Nights	Ten-Minute Periods	Meteors Recorded	Average No. of Observers
Baltimore, Md.	K. Delano	33	226	296	1
Bexleyheath, England	K. Herbert	3	32	10	1
Boise, Idaho	J. Westby	8	72	179	2
Brunswick, Ohio	H. Decker	3	19	10	1
Caguas, Puerto Rico	A. Nieves	4	40	86	2
Caney, Kansas	P. Holt	4	32	11	1
Cape Elizabeth, Me.	R. Dole	10	143	169	1
Cedarhurst, N.Y.	E. Heinhold	7	42	30	1
Centreport, Pa.	R. Machemer	14	183	346	2
Chicago, Ill. #2	D. Fretland	3	32	66	1
Clayton, Missouri	D. Megginson	21	173	137	1
Cleveland Hts., Ohio	J. Breckinridge	1	5	6	1
Des Plaines, Ill.	G. Rippen	23	215	101	1
Edmonton, Alta. #1	Dr. Gowan	3	17	17	3
Edmonton, Alta. #2	E. Milton	7	47	318	5
Elyria, Ohio	G. Diedrich	2	12	10	3
Emporium, Pa.	D. Regester	5	35	19	2
Fort St. John, B.C.	R. W. Brown	2	13	5	1
Fort Wayne, Ind. #2	D. Nelson	8	91	35	1
Franklin Park, Ill.	A. Demos	5	42	3	1
Guayama, Puerto Rico	R. M. Baquero	11	131	87	4
Hamilton, Ont. #1	J. A. Winger	4	45	95	5
Ions, Ohio	D. Hansen	4	57	65	2
Islip Terrace, N.Y.	W. Webster	28	197	173	1
Kingston, Jamaica	E. C. Melville	2	12	24	4
Lodi, Calif. #1	R. Birch	6	67	45	1
Lodi, Calif. #2	P. Sheehan	8	81	196	1
Los Angeles, Calif.	T. Quinn	9	54	101	1
Lucerne, Switzerland	Dr. E. Roth	8	56	120	1
Minneapolis, Minn. #1	R. H. Scrimshaw	15	90	56	2
Montgomery, Ala.	J. Connell	2	6	13	1
Montreal, P.Q.	Miss. I. K. Williamson	10	113	71	5
Moose Jaw, Sask.	L. Larsen	3	48	202	8
Morton Grove, Ill.	R. Jornd	2	11	7	1
Newark, Ohio	M. Obrien	6	54	50	1
New York City, N.Y. #4	A. Pearlmutter	37	317	1757	1
Omaha, Neb.	C. Moroson	6	37	117	2
Ottawa, Ont. #1	Miss M. S. Burland	12	442	1086	5
Ottawa, Ont. #2	E. G. Lomas	1	1	1	1
Pittsburg, Pa.	W. A. Feibelman	18	140	166	1
Poughkeepsie, N.Y.	F. Greer	7	40	21	1
Regina, Sask. #1	E. Majden	8	73	327	5
San Jose, Calif.	S. Bienda	3	15	130	5
Scranton, Pa. #1	J. Kosmo	3	18	21	1
Shediac, N.B.	A. R. MacLennan	1	9	4	1

Location	Name	Nights	Ten-Minute Periods	Meteors Recorded	Average No. of Observers
Shelby, Ohio	J. Horner	2	5	4	1
Teaneck, N. J.	Miss J. Shelby	8	51	89	1
Vancouver, B. C. #1 (Kitsilano)	N. Eisner	2	7	43	3
Western Springs, Ill.	R. Rexford	7	225	735	5
West Nanticoke, Pa.	H. Humphries	2	12	1	1
Woonsocket, R. I.	R. Latour	3	18	14	1
Arlington, Calif.	H. E. Kaiser	2	25	247	11
Aster, N.Y.	G. Bergman	4	42	128	1
Bayside, N.Y.	J. Conte	5	76	149	1
Beacon Falls, Conn.	T. J. Bolinski	30	292	565	1
Brooklyn, N.Y. #3	J. S. Levine	4	16	9	1
Broomall, Pa.	R. Field, Jr.	1	6	1	1
Calcutta, India	S. I. Ghosh	2	23	—	1
Centreville, Va.	M. E. Bishop	19	131	237	1
Cleveland, Ohio	K. Hicks	6	22	18	1
Danville, Ill.	M. Zillman	1	3	3	1
Dayton, Ohio	S. H. Moon	1	5	8	1
Dyersburg, Tenn.	J. Jinkins	3	20	42	3
Elkgrove, Calif.	J. York	6	54	190	1
Elkton, Md.	P. Miscall	4	33	44	1
El Paso, Texas	Mrs. L. McCormick	1	15	1	1
Haliburton, Ont.	Miss M. S. Burland	1	6	58	6
Hamilton, Ont. #2	D. Murthie	3	10	7	1
Houston, Texas	D. Milon	8	106	612	3
Ichinomiya, Aichi, Japan	K. Komaki	6	44	67	—
Johannesburg, S. Afr.	J. H. Botham	9	66	85	1
Kanaya, Japan	K. Komaki	40	375	835	1
Kibi, Japan	Mrs. F. Iwasaki	31	225	367	1
Kingston, Ont.	A. Douglas	1	7	5	1
Kishiwada, Japan	U.S. School	9	127	337	—
Leavenworth, Wash.	S. Emig	8	107	207	2
Little Falls, N.J.	Wm. Hackos	5	39	14	1
Malate, Manila, Philippines	B. P. Seno	8	80	7	2
Merrimac, Mass.	R. B. Kelly	6	79	51	1
Minneapolis, Minn. #3	B. Steger	8	98	220	1
New Bedford, Mass.	R. Jepson	1	7	16	1
New York City, N.Y. #7	S. S. Chizzoniti	2	2	4	1
Peterbrougho, N.H.	R. Nickols	1	3	6	7
Philadelphia, Pa.	J. Nemiroff	2	32	1	2
Plainview, Ark.	E. T. Hyde	1	6	1	1
Port Alice, B.C.	H. Barclay	7	26	12	1
Pretoria, S. Africa	S. C. Venter	14	156	515	2
Red Bluff, Calif.	F. Wyburn	13	86	1	1
Regina, Sask. #2	Mrs. J. Hodges	1	22	11	3

Location	Name	Nights	Ten-Minute Periods	Meteors Recorded	Average No. of Observers
Richmond, Va.	T. O'Keefe	2	12	18	4
Rio de Janeiro, Brazil #1	A. Fucs	16	124	81	2
Rio de Janeiro, Brazil #2	P. Silva	4	24	14	1
Rio de Janeiro, Brazil #3	H. Bucher	42	297	259	2
Rio de Janeiro, Brazil #4	H. Melzer	1	9	1	1
St. Albans, W. Va.	R. W. Smith	7	41	37	1
St. Paul, Minn.	R. A. Gorkin	14	98	85	1
Salem, Ohio	V. Taus	8	114	461	3
Salem, Oregon	R. M. Bales	2	14	4	1
Santa Maria, Calif.	d. W. Savage	5	30	9	1
Sebastopol, Calif.	C. McLendon	4	36	27	2
Sheffield, Ala.	R. May	7	49	45	1
Springfield, Mass.	D. W. Daury	3	18	26	1
Turtle Island, Ont.	Miss L. Remmel	2	4	3	1
Vancouver, B.C. #2 (Kerrisdale)	M. T. Taylor	2	12	101	4
Wakayama, Japan	A. Kamo	26	383	907	1
Washington, D.C.	W. L. Isherwood	1	6	3	4
Wellington, C.I., New Zealand	N. K. Keen	11	70	85	1
Worthington, Ohio	H. Balsiger	1	6	12	6
	Grand Total		7722	14997	

Again, I would like to thank those who have assisted in this programme. The names of all taking part will appear in Bulletin No. 2 which will be distributed shortly. May I remind observers that this year we have the Perseid maximum coming at the dark of the moon and that we hope to have a very complete coverage of this important shower. Additional volunteers will be welcome. For free observing forms and instructions write Meteor Centre, I.G.Y., National Research Council, Ottawa, Canada.

REFERENCE

Millman, P. M. *Jour. R.A.S.C.*, vol. 52, p. 29, 1958.

VARIABLE STAR NOTES

By Margaret W. Mayall

The American Association of Variable Star Observers, Cambridge, Mass.

In recent years more and more interest is being shown in the group of variables involved in or associated with nebulosity, and known as T Tauri, RW Aurigae and Orion-type variables. They occupied a prominent place in the discussions at the Symposium on Non-Stable Stars, held during the 9th General Assembly of the International Astronomical Union at Dublin in 1955. It was pointed out at the Symposium that much more observational material, both spectroscopic and photometric, is required before any of the problems can be solved. Most of the stars of these groups show sudden, very rapid changes in brightness, often of the order of a magnitude or more within a few minutes.

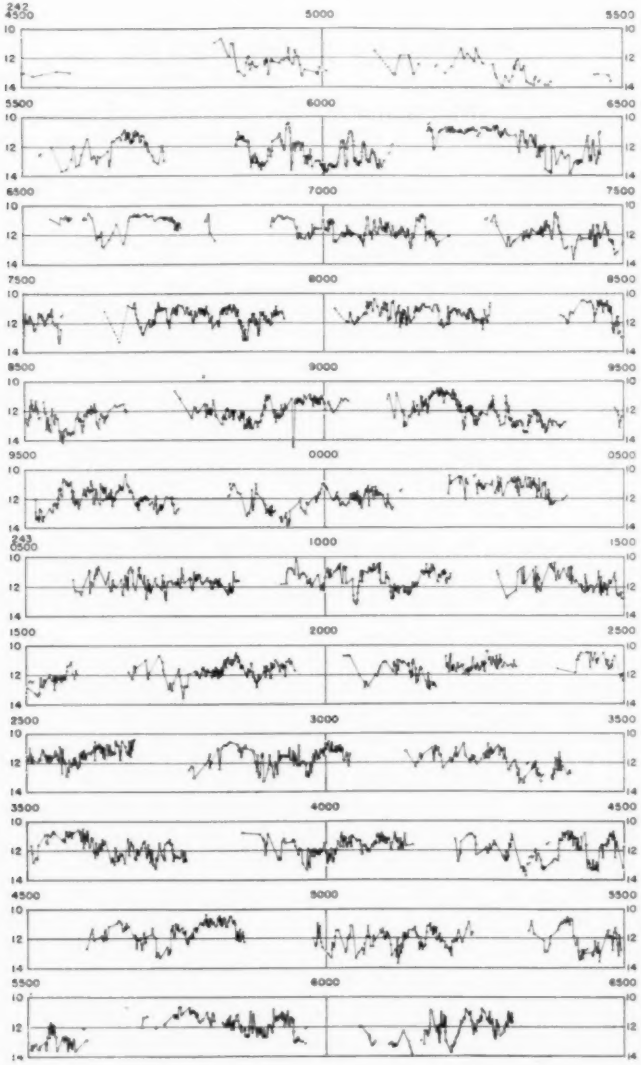
The spectra of these stars are peculiar, with underlying absorption spectra with dwarf characteristics, but anomalous wide and diffuse absorption lines, in addition to H-alpha and CaII emission lines. The T Tauri and RW Aurigae variables are usually of types F and G, but it is now thought that a whole series of somewhat similar objects, with spectra ranging from O through M, and including stars like AE Aquarii and UV Ceti, may be closely related.

The following notes concern the A.A.V.S.O. observations of some of the variables classified as of RW Aurigae, T Tauri or Orion type in the *General Catalogue of Variable Stars* by Kukarkin and Parenago.

Among the most difficult variables to observe are those which are involved in variable nebulosity. Three well-known examples of such objects are 041619 T Tauri, 063308 R Monocerotis, and 185537a R Coronae Australis. In each case, the variable is located at the tip of a triangular or funnel-shaped patch of nebulosity, which varies, perhaps, more than the star itself. The difficulty of estimating the brightness of such an object can be imagined. Some observers attempt to ignore the nebulosity and give an estimate of the star itself, while others try to imagine what the total brightness would be if all the light could be drawn together into a star-like image. Another important observing factor is the light-gathering power of the instrument used.

The most dependable observations of these stars are from a long series of observations by one observer using the same instrument, under similar observing conditions. Also, we should have a few careful runs of observations made every few minutes during an evening, in order to determine the short rapid variations.

RR Tauri 053326, has been on the A.A.V.S.O. observing programme for about 35 years. The accompanying light curve shows daily mean values of observations from 1926 through April 1958. The extreme range of brightness during this time is from 10.4 to 13.8. A close inspection of the light curve shows little hint of any significant regularity of period. If there is any real periodicity, it would be a combination of several overlapping periods, one between 40 and 60 days, another around 200 days, and still another longer one of about 500 days. In addition to



Light curve for RR Tauri 053326 from 1926 through April 1958.

Observations received during March and April 1958: A total of 6,300 observations was received, 3,136 from 55 observers in March, and 3,164 from 59 observers in April.

Observer	March		April		Observer	March		April	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Adams, R. M.	80	139	48	70	Major, M. H.	..	..	2	4
Allin, R.	6	9	23	53	Melville, E. C.	8	12	7	9
Anderson, C. E.	87	145	89	117	Miller, R. W.	29	38	18	24
Anderson, E.	6	19	6	28	Montague, A. C.	30	35	21	23
Ball, A. R.	..	..	26	71	Morgan, F. P.	23	39	20	39
Beidler, H. B.	..	..	13	13	Nemiroff, J.	1	1	..	..
Breckinridge, J.	3	3	2	2	Oravec, E. G.	203	414	226	465
Buckstaff, R. N.	6	9	..	..	Osypowski, T.	..	..	10	11
Carlisle, J. H.	1	4	1	3	Parker, P. O.	45	50	48	51
Charles, D. F.	..	..	3	10	Pearcy, R. E.	5	5	2	2
Conklin, J. H.	5	5	..	..	Peltier, L. C.	24	36	2	4
Cragg, T. A.	191	194	13	13	Peters, P.	..	..	13	13
Darsenius, G. O.	12	31	14	67	Pilcher, F.	3	3	1	1
Diedrich, DeL.	1	1	5	6	Price, F. J.	16	29	23	56
Diedrich, G.	5	8	6	9	Primavera, S.	1	1	..	..
Engelkemeir, D.	8	13	7	14	Quester, W.	8	20	7	21
Erpenstein, O. M.	11	20	1	1	Renner, C. J.	65	65	89	89
Estremadoyro, V. A.	..	..	8	9	Rizzo, P. V.	11	11	8	11
Fernald, C. F.	58	66	194	225	Robinson, L. J.	7	42	7	14
Fletcher, D. M.	7	29	..	..	Rosebrugh, D. W.	13	85	11	58
Ford, Clinton B.	144	145	136	136	Rosenfield, C. C.	4	4	21	52
Garland, G.	6	73	4	69	Rosenfield, D. A.	..	..	5	7
Gemberling, R. H.	16	22	50	70	Royer, R.	3	3	..	..
Godfrey, N. B.	..	..	5	5	Rudolph, R.	23	77	24	79
Goodsell, J. G.	4	4	3	3	Schrader, M. I.	..	..	4	12
Halvorson, D. O.	9	61	..	..	Sharpless, A. P.	16	17	8	8
Hartmann, F.	110	116	117	124	Sloan, M. A.	2	4	..	..
Hein, G. J.	..	..	3	4	Solomon, L.	18	23	27	35
Hutchings, N.	5	7	..	..	Taboada, D.	143	215	139	232
Kelly, F. J.	10	13	10	13	Tsai, C. H.	20	24	..	..
de Kock, R. P.	104	545	112	488	Valdez, M.	20	119	18	94
Kubanoff, J. H.	..	..	1	1	Venter, S. C.	11	12	..	..
Lacchini, G. B.	9	17	..	..	von Rosenvinge, H.	11	46	16	33
Lowder, W. M.	..	..	18	22	Wend, R. E.	..	..	24	59
Magruder, R. S.	8	8	6	6	Wilson, C. F.	..	..	6	6

these, there is a definite indication of the extremely rapid variations occurring within a few minutes, which are cammon to these nebular variables.

The spectrum of RR Tauri has been classified as gA2e by Dr. Herbig, who found its hydrogen lines similar to those of stars of luminosity classes II or III.

The T Tauri, RW Aurigae and Orion-type variables show a strong tendency to grouping. The variable T Orionis 053005a, is in the heart of a large group of the Orion-type variables associated with the Great Orion Nebula. Among the ones being observed on the A.A.V.S.O. programme are, in addition to T Orionis, TU, AD, AE, AF, AK, AN, AQ, KX, LP, NU, V359, V361, and V372. Several observers are taking a special interest in this group of variables, but they have a very difficult problem, to observe variables so involved in the nebulosity.

Another group of these stars on the A.A.V.S.O. programme is in the southern constellation of Corona Australis. Four variables, R, S, T, and TY, are involved in the

bright and dark nebulosity; R CrA, as mentioned above, is in the point of a bright triangular patch of variable nebulosity. TY CrA is the brightest of the group, and is sometimes brighter than 10th magnitude. They are all erratic and have sudden changes of brightness.

A variable which is probably related to these RW Aurigae and Orion-type variables is 201520 V Sagittae. It has been a puzzle for many years, and has had many different classifications assigned to it. Its spectral type is Ob, and many observers have considered it to be an old nova, whereas others have computed various periods, such as 17, 70, and 530 days. The visual light curve of V Sge is very similar to the curve of RR Tauri, shown in these notes. It has an overall variation of about 3 magnitudes, and at times has indications of overlapping short and long periods. Many A.A.V.S.O. observers have noted rapid variations of one magnitude or more within a few minutes or during an evening of observing.

Variable Star Observing in Scandinavia. An excellent article on Observing Variable Stars, written by Gunnar Darsenius, was published in the *Popular Astronomisk Tidskrift*, Häfte 1-2, 1957. For many years, the Astronomisk Selskab (Observatoriet, Ostervoldgade 3, Kobenhavn K, Denmark) has had a small, but very assiduous group of experienced variable star observers. Astronomical literature contains many references to their fine work. Each year, through the kindness of their Director, Axel V. Nielsen, their observations of SS Cygni are combined with A.A.V.S.O. observations to form the continuous light curve published in these notes. The article by Mr. Darsenius will undoubtedly do much to arouse the interest of more amateurs. He discusses observing methods and instruments, and illustrates his description of the different types of variable stars with many light curves.

A.A.V.S.O. Nova Search Report (From George Diedrich, Chairman):

Observations of Nova Search Areas were made by the following 14 observers for a total of 159 area-nights. Each name is followed by the number of observations made in January, February, and March, 1958: Richard Bates–0, 15, 0; Frank J. DeKinder–8, 6, 9; Mrs. DeLorne Diedrich–0, 6, 4; George Diedrich–0, 11, 11; Geoffrey Gaherty, Jr.–0, 0, 4; G. Harper Hall–4, 3, 0; Jack Morrison–1, 6, 9; David L. Sands–0, 7, 1; George Wedge–1, 0, 0; James F. Wesling–0, 0, 3; Miss I. K. Williamson–5, 5, 6; Mrs. Katherine Zorgo–4, 5, 13.

Some reports that have recently come in and have not been reported to date include Andrew J. Keefer, Jr.–(All 1957)–April–24; May–38, July–16; and Karl A. Wells–September, 1957–4.

Most of these zeros in the January column merely mean that those people were credited with observations for that month in the last report–the number of reports received too late for that report made it necessary to include a January listing again this time. All reports are welcome. Only if *you* are observing will *you* stand a chance of finding that nova. Incidentally, there was a nova in Ophiuchus discovered at the Observatorio Astrofisico Nacional, Tonanzintla, Mexico, but it only got to 8th magnitude on November 18, 1957. Remember our motto–"Keep Looking".

REVIEW OF PUBLICATIONS

Solar Eclipses and the Ionosphere edited by W. J. G. Beynon and G. M. Brown. Pages x plus 330, 7½ × 10 in. London and New York, Pergamon Press, Price $21.00.

This volume is a record of the proceedings of a symposium held under the auspices of the International Council of Scientific Unions Mixed Commission on the Ionosphere. Included are the 53 papers presented, discussions of these papers, and a bibliography of eclipse papers.

In order to study the ionosphere of the earth one must investigate both the physical conditions in the ionosphere and the particle and electromagnetic radiation from the sun. Total solar eclipses of the sun provide excellent opportunities to investigate both of these problems. Two of the seven sections of the book are devoted to solar radiation. In the first of these the authors have looked for the source of the radiation which produces the various layers in the ionosphere and find that it may be Lyman-alpha and soft X-ray radiation. In the second section radio-frequency radiation from the sun is investigated. By observing this radiation throughout an eclipse it is possible to determine what the sun looks like at various radio frequencies and also to pinpoint regions on the solar disk which are emitting strongly.

The largest section deals with the observations of the various layers of the ionosphere during eclipses and the interpretation in terms of the physical processes occuring in the layers. From these observations the effects of the sun's radiation can be determined and also studies of the corpuscular radiation can be made.

This book will be valuable for those who are working in ionospheric research. It has the disadvantage that, being a collection of papers, it cannot be as methodical in its treatment of the problem as a book written by a single author. The advantage is that it does present results and views that are new.

In the opinion of the reviewer a collection of papers of this kind should be published in the same economical form as standard journals. In this way the cost is reasonable and any person desiring the collection of papers can afford to buy it. Many proceedings of symposia are now printed in this way. The publishers of this book have, however, printed and bound it in very expensive manner and have placed a price on it

which puts it beyond the reach of most individuals. The result is a beautifully bound book which is more likely to find its way into a glass case than onto the research worker's desk where it belongs.

J. B. Oke

The Background of Astronomy by Henry C. King. Pages 254, 5¾ × 8¾ in. London, C. A. Watts and Co. Ltd., 1957. Price 28s.

Dr. King, now Director of the new London Planetarium and author of the excellent *History of the Telescope* which was reviewed in vol. 50, p. 129, 1956, of the Journal, has tried his hand again at an historical topic. In *The Background of Astronomy* he has tried to set the stage, as it were, for an appreciation of modern astronomy. He has chosen the period from the obscure beginnings of astronomy to the close of the sixteenth century and has tried to show, as he puts it in the preface, that the findings in this period are no less stimulating than those which followed the invention of the telescope.

If this was really the purpose of the author, then, in the opinion of this reviewer, he has put too much emphasis in this small volume on the folk lore and the mythology and the superstition and the astrology of those early times, and too little on the truly inspiring efforts of those astronomers who managed to hack their way through the jungle of confusion and catch glimpses of the truth. It is true, of course, that we must understand the times and the beliefs of the times if we are to appreciate the efforts, both successful and unsuccessful, of the real astronomers of those times; but, on the other hand, an overemphasis on the unwholesome side of ancient astronomy may leave the unwary reader with an actual lack of that appreciation.

Yet, for all that, Dr. King's book is very readable; the anecdotes and the bits of star lore are fascinating, and the stories of the astronomers, though sketchy, are accurate. In at least one place there is a statement which must be challenged, however. On page 70, the author states that "we know now that in all probability [the meteorite which fell in Aegos Potami in 468 B.C.] came from Halley's comet which made a close approach to the earth in 467 B.C.". In fact, the evidence is so much against the association of meteorites with comets (despite the obvious association of *meteors* with comets) that the coincidence of the dates, even if exact, would have to be discounted.

John F. Heard

Rockets, Missiles and Space Travel (revised and enlarged edition) by Willy Ley. Pages 528; 5 ½ × 8¼ in. New York, The Viking Press Inc., 1957. Price $6.75.

First published in 1944, this book has now had eleven printings, and two complete revisions. This latest version is a well-written, authoritative, popular history of the subject. However, the recent Soviet advances in the field may well necessitate another revision before very long. (The American Vanguard satellite is, of course, described by Mr. Ley.)

The book makes fascinating reading for anyone interested in the subject of rockets, artificial satellites, etc. Beginning with the dreams of the ancient Babylonians, the history extends up to the end of 1956—with particular emphasis on the twentieth century. Mr. Ley then enters the field of speculation to describe some current concepts of spaceships. An excellent bibliography of books and periodicals is included as an appendix.

WILLIAM R. HOSSACK

The Stars by H. A. Rey. Pages 144; 8½ × 11 in. Boston, Houghton Miffin Company, fourth printing, 1956. Price $6.00.

The Stars is a beginner's guide to identifying the constellations. Throughout the book the English names for the constellations are used, instead of the more usual Latin names. The author has drawn the guide lines between the stars in a constellation to indicate the shape which the name suggests; this has been done with considerable success. Following a brief introduction to the motions of the stars are sketches of the constellations. This section is followed by twelve "calendar charts", which show where and when to look for a given constellation. The last third of the book gives brief explanations of some of the basic astronomical principles: the celestial sphere, seasons, precession and so on; a table showing where to find the planets up to the end of 1960 is included.

The book is liberally illustrated with delightful sketches by the author. The end papers consist of four horizon maps, one for each season, while the jacket of the book opens out to a large polar projection map showing all the constellations visible from the mid-northern latitudes. This is a book which can be recommended as an introduction to the appearance of the sky.

RUTH J. NORTHCOTT

Catalogue of Star Clusters and Associations by G. Alter, J. Ruprecht and V. Vanýsek. Pages 40 plus 1566. Prague, Czechoslovak Academy of Sciences, 1958 (in English). Price 140 kcs.

A long-needed working catalogue of all star clusters is now at hand. This work by G. Alter, J. Ruprecht and V. Vanýsek is however, far more than the name alone indicates. To be sure, it is a valuable catalogue of all clusters known at the present time, 576 galactic, 46 associations, and 117 globular, each section compiled by one of the three authors in the order mentioned. It is the first catalogue of galactic clusters to be published in a quarter of a century.

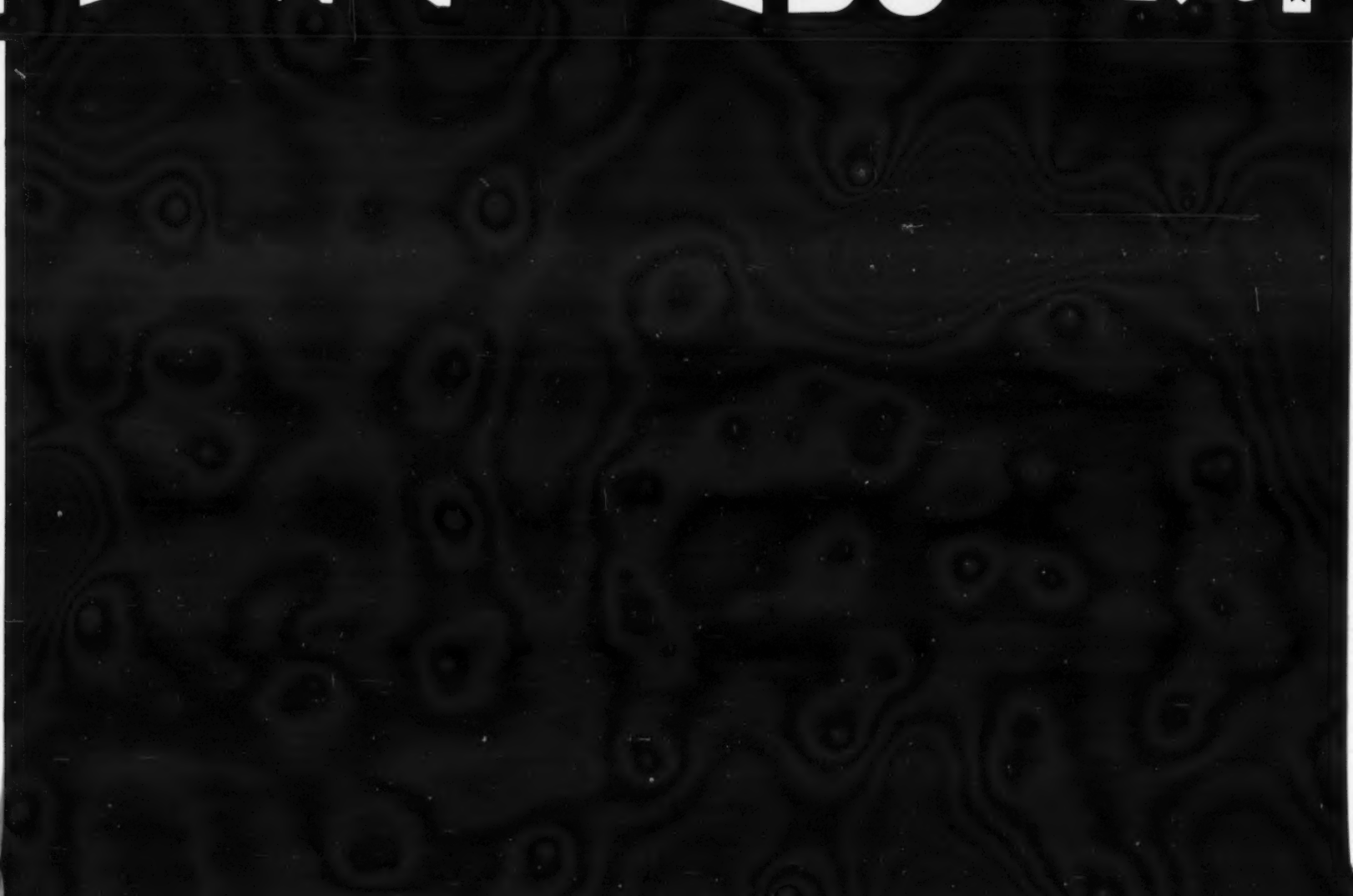
More than just a catalogue, it is also a bibliography of references complete from 1900 under each individual cluster, including references to clusters in the text of an article, a colossal task. It is on 783 cards, 8.2 by 5.8 inches, contained in a hinged heavy cardboard box 8¾ by 8½ inches by 5½ high. The cards are arranged (within each class of cluster) by right ascension, and are paged consecutively, on both sides, up to page 1566. A package of extra cards is provided for expansion. The cards are headed with designation of object, equatorial co-ordinates for 1900, 50-year precessions, galactic co-ordinates and quantities like angular diameter, colour-index, and many others. The card for each cluster contains more than the reference itself, as it lists pertinent information from it. A 40-page pamphlet of description and explanation accompanies the card catalogue.

The only improvement in the bibliographical section of the catalogue this reviewer would have liked to see is a strict chronological listing of references. A chronological order is followed generally, but not strictly. This would have increased the work of compilation, but saves time for anyone checking to find a given reference.

It is inevitable that any such extensive compilation will contain errors, some inherent in the original papers and others creeping in from the abstracting. The authors propose to issue each year a supplement to contain all new information which appears, and to correct any errors and omissions in the old.

For a work of this magnitude in the unusual format of large cards, the price is moderate. We consider this catalogue an essential for any observatory interested in any kind of star cluster.

HELEN SAWYER HOGG



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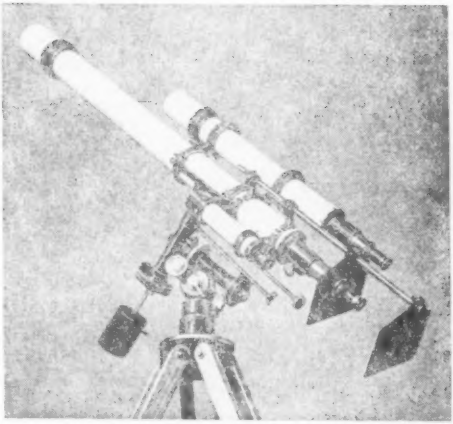

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